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CONCERNING THE IMPORTANCE OF THE STUDY OF PLANT DISEASES IN HIGH SCHOOL AGRICULTURE.

BY L. R. TEHON,

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Plant diseases, because they are constantly increasing in importance as factors limiting crôp production, are receiving proportionately more attention not only at the hands of trained experts, but also from farmers, fruit growers, truck-farmers, green-house operators, and nurseries; and one may expect to see an increasing devotion to the study of their causes, and control measures, even in the elementary agricultural classes of our secondary schools. This should be especially true in our township and agricultural high schools, where the student body is drawn largely from the surrounding countryside. For these schools are, in a very real sense, the trainers of the farmers of tomorrow; and it is essential that the farmers of tomorrow be so broadly and wisely trained as to give intelligent and willing cooperation in attacking the important problems they will have to face.

Among their vital problems, it is certain that the prevention and control of plant diseases will be among the most important.

It is conceivable that the widespread knowledge of danger to crops from insect attack is due to the facility with which cause and effect may be determined when the cause can be seen as a living, moving thing; but it has not been so easily understood that many of the greatly feared pestilences attacking crop plants could be due to parasitic organisims of a fungous or bacterial nature visible only under the powerful lenses of a compound microscope. This is why plant diseases, although known to mankind since early biblical time, have nevertheless been shrouded in superstition and mystery until very recent years. In the light of our present knowledge one must needs read with

wonder how an early epidemic of stem rust, destroying the grain fields of the Puritans, was looked upon as sudden punishment from Heaven for unbelievable cruelties practiced in the persecution of the Quaker sect.

The study of plant diseases first took form as a science as recently as 1870, but knowledge has developed and spread to such an extent that demands have already arisen for the control of well established diseases, and for the immediate eradication of newly introduced diseases of a dangerous character. There is now in progress a concerted effort in thirteen adjacent states to stamp out the stem-rust disease of grains. A large amount of endeavor was expended to control the blight which endangers the chestnuts of the Atlantic region; control measures are under way to stop the spread of blister rust which threatens our white pine forests, and the citrous growers of Florida have used most drastic measures in eradicating the citrous canker. Millions of dollars have been spent on these programs; and even now the state of Illinois is spending thousands to eradicate from a small area within its boundaries, the recently introduced flag smut of wheat, thus preventing it from spreading throughout the wheat-growing region.

One of the most important conditions in all attempts to control or eradicate plant diseases is the dependence of the program upon the intelligence of those persons most directly concerned in the ultimate benefits. It has been the usual experience that where these people are possessed of a type of training which enables them to grasp the real meaning of the measures employed, their whole-hearted cooperation has assured the success of the undertaking, whereas, under circumstances less favorable, their lack of knowledge of the causes of plant diseases and of control methods has provided obstacles well nigh insurmountable.

We may say with assurance that the success with which plant diseases are combated during the coming generations must depend upon the existence among farmers generally of a fundamental knowledge of their nature, their causes, their means of spreading, and of at least a few of the simpler measures for control. There is no better opportunity for developing such knowledge than the elementary agricultural courses given to the youth of our farms through secondary schools.

While it may be neither wise nor profitable to endeavor to go too thoroughly into details in such a study, there are certain concepts which should remain in the student's mind. These concepts

will probably be best indicated by the presentation of the following category: First, that plant diseases are important agents in the destruction of growing crops; second, that they are due to the attack of minute parasitic organisms, fungi and bacteria; third, that they are spread by "spores," and under favorable circumstances may become truly epidemic; and fourth, that they can always be controlled by the use of proper preventive measures.

One of the easiest ways of attracting the student's attention, and awakening his interest in plant diseases is by displaying some especially striking specimens of diseases such as the oftentimes marvelous malformations produced on ears of corn by the attack of smut, or the medusae-like "apples" from the cedar tree in early spring. The plain statement that plants bearing such malformation are *sick* leads easily to a consideration of the various types in which diseases manifest themselves—leaf spots on leaves of apple, pear, grapes, strawberries, etc.; cankers and blights of stems and blossoms on apple, on pear, on brambles, etc.; "damping off" of seedlings; root rots of many kinds both in the field and on stored crops; smuts and rusts of grains; malformations, such as crown gall, black knot of plum and ergot in rye; fruit rots on both the tree and in storage; and wood rots of forest trees and lumber.

The common occurrence of diseases and their dangerous aspect can be easily emphasized by encouraging students to look for and collect specimens among the common plants of the field, the berry patch, the garden, and the weeds and wild plants of the wayside. Whatever material is brought in should be subjected to an examination under the microscope to show the presence of a fungus and to show the "spores" which serve to spread the disease to others of its host plants. Short periods may be selected at intervals and employed to advantage in summarizing the diseases brought in and in outlining control measures.

For special class and laboratory or field exercises, certain typical forms of disease may be studied by the use of common and well known examples. Diseases of a bacterial nature are typified by the "fire blight" of pear and apple trees. A small drop of the exudate from a stem or twig canker, when placed under the high-power lens of a microscope, will show swarms of the motile bacteria which cause the disease. The smuts of corn and grains afford excellent illustration of the power possessed by fungi of producing limitless numbers of spores, and

the germination both of these spores, and of those from the orange rust of blackberries, in moist chambers under the microscope will show how they function in spreading infection among plants. It is even possible, through the use of a glass microscope slide, covered with a thin film of vaseline, which has been exposed to out-of-door air currents for an hour, to demonstrate that fungus spores are being constantly carried by the winds and that they need only to alight on their proper host, under favorable circumstances, in order to produce damaging infections.

Among the things most in need of emphasizing, by the use of suitable examples, is the phenomenon of heteroecism—a technical word that conveys in concise form the fact that certain kinds of parasitic fungi require, not merely one, but usually two wholly unrelated host plants upon each of which they pass a definite portion of their life cycle. This fact is of special importance because it provides, through the destruction by man of the less important of the two hosts, a practical means of controling or, possibly, even of eradicating the disease. In fact this method of control is now in use in two programs, one for the control of stem-rust through the eradication of the barberry, and the other for the control of white-pine blister rust by eradication of gooseberry bushes near valuable whitepine forests. Material for the study of this type of disease can be readily obtained in most places because of its variety and abundance. A few examples may be suggestive: Apple rust and the cedar apple, crown rust of oats and the leaf spot of buckthorn; stem rust of grains and the "cluster-cup" of the barberry.

While any teacher who has followed the main points outlined above will undoubtedly have explained the principle means of disease control for local conditions and will have emphasized the proverbial value of the ounce of prevention, it is not unreasonable to suppose that one of the broader aspects may have been touched upon only incidentally. Yet, as the significance of plant diseases becomes more generally understood, those on the farms will be called upon to pass judgment upon or to lend support to control programs of a far reaching character, and it is essential that they should be able to act wisely. Herein lies the value of explaining in some detail the principles underlying state and national quarantine regulations and extensive as well as expensive eradication campaigns.

As a final step, it can not be urged too strongly upon the teacher that, whenever he encounters a disease which he is

unable to diagnose, he should send a representative specimen to some recognized expert in his state. This will not only increase his own knowledge, but may occasionally be a real service to agriculture. It was in just this way that, not long ago, a serious disease was discovered shortly after its introduction into the United States, making it possible for steps to be taken to insure the eradication of the disease before it had spread beyond control.

THE PROJECTION OF THE BROWNIAN MOV ENTS.

By Walter O. Walker,
High School, Carthage, Mo.

The following method for the projection of the Brownian Movements has been worked out in the laboratory of the author during the past year. It consists of a method by means of which a moderately equipped laboratory can assemble the apparatus necessary for the projection of this exceedingly interesting phenomenon. The Brownian Movements have been observed for quite a number of years, but only recently has their especial significance, as related to the molecular movement, created for themselves any importance other than their phenomenology.

It is quite possible to show these Movements in a clay suspension or a gold or resin colloidal solution, making use of the standard microscope giving a magnification of 450 or over. However, where the time is limited, and the classes are large, this method is too slow and cumbersome for class usage.

The projection of these Movements occupies only a few minutes of the class period, and is easily and rapidly produced. Anyone understanding the operation of a microscope and a projection lantern can make the "set-up" and get the proper projection in five minutes.

Apparatus.

Any type of arc-light lantern will do, it being necessary to get the brightest source of light possible, prefereably from one point. The more modern lanterns, equipped with high-powered bulb lights provided with suitable reflectors, give very good results. The brighter the light, the clearer the image.

The projection lens is removed from the lantern, since only the condensing lenses are necessary.

The instrument used by the author gave a magnification of about 450. This proved high enough to obtain a clear image.

The microscope must be of the turn-down type. It is turned down with the tube pointing toward the screen and is mounted on a stage in the direct line of light from the condensers. The microscope is placed at such a distance from the lantern that the objective of the microscope is at the focii of all the beams of light from the lantern. This gives the maximum illumination. If an Abbe condenser is used on the microscope, the foregoing position of the microscope is not so important, providing all the light from the lantern passes through the Abbe condenser.

The eye piece is removed from the microscope. Care must be taken that the barrel of the microscope is perfectly aligned with the beam of light. This can best be determined when all other adjustments are made since the appearance of the image on the screen will be affected by imperfect alignment.

The screen is mounted about ten feet from the lantern. This distance may be varied, if by so doing a better image is secured. The screen must be of some material possessing a high reflective power. Glazed white paper proves to be very satisfactory, and at the same time, costs very little. Special aluminum screens may be obtained from optical companies. Lime screens may be prepared by plastering a lath work. or a section of the wall. with slacked lime. This latter screen is widely used in Germany, where it is mounted on rollers for easy conveyance from one room to another. The screen need not be larger than four feet square.

After experimenting with gold, clay, sulphur and resin colloids, it was found that the resin colloid gave the best results. This colloid is prepared by saturating 5 cc. of alcohol with resin. The solution is then poured into 5 cc. of water, producing a milky appearing colloid, opaque to light, excepting in thin layers. It retained its characteristic colloidal properties for several months after preparation. It is best to test this colloid for the Brownian Movements before the projection is attempted.

A finely ground sample of raw rock phosphate, kindly donated by J. E. Adams, of Purdue University, showed very excellent Brownian Movements of about the same intensity as the colloidal resin. The presence of particles too large to be affected by molecular bombardment deprived the field of its uniformity. However, this illustrates very excellently the fact that only the smallest particles can be set into vibration by the bombardment of the molecule.

PROJECTION.

The actual projection method is as follows: The lantern is operated and the microscopic position varied so as to get the maximum illumination. The screen is set up as directed, perpendicular to the beam of light, and on the same level. The slide is prepared by placing a drop of the colloidal solution on an ordinary microscopic slide, and covering with a cover glass to eliminate evaporation. (The heat from the lantern may be cut off by a water cell placed between the condensing lenses. This will eliminate any danger of over-heating the objectives of the microscope.) The microscope is adjusted in the usual fashion, until a clear image is secured. If the foregoing directions are observed, the projection of the Brownian Movements becomes as easy as any type of microscopic projection.

It is hardly necessary to add that the foregoing combination of apparatus may be used for any type of high or low microscopic projections. It should prove of great value to teachers of science.

BARBER'S STANDARDIZED SCIENCE TEST FOR GENERAL SCIENCE.

It takes nowadays a pretty well educated person in science to be able to successfully teach the subject of general science, because it embodies so many different sciences if the work is to be done efficiently. These little tests that Mr. Barber has prepared for general science teachers cover, in a remarkable degree, all phases of the work. Any general science teacher who has the interest of his work at heart should prepare himself with a set of these tests. They may be had from A. B. Barber, Clayton, New Mexico.

POSITION OF FEET IN FLIGHT IN CERTAIN BIRDS.

Here are several apparent "rules" in bird life that have interested me for some time, and they are passed on to the readers of *The Condor* for what they are worth.

1. All water birds in flight extend the feet behind.
2. All web-footed birds, with short tails, spread the toes in flight, the membranes apparently acting as an elevator or rudder. This group includes the murres, murrelets, auks, and puffins.
3. All perching birds in flight fold the legs forward under the feathers.

All the short-tailed, web-footed birds that I have had under close observation, when getting under way do spread the toes, placing them side by side to form a wide flat surface, which is no doubt useful in flight. By the tine these birds may have attained their regular speed, possibly the toes are relaxed, but they are then as a rule too far distant for accurate observation. I am not so certain that loons follow this rule. Grebes, which are lobe-footed, spread the lobe flat out in rising from the water and, I think, close the toes after attaining full speed.—[*The Condor*.

A METHOD OF SCIENCE PROCEDURE.

By E. S. Obourn,

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As a teacher of science in secondary schools the writer has had very good results with this method which has been thoroughly tried out. It is being passed on at face value with the hope that some one may gain some usable points from it. In planning and using this device, effort has been made to conform as closely as possible to the fundamental psychological principles underlying the learning processes. This article is written from the standpoint of physics but has been used with very slight modifications in chemistry classes.

The physics classes with which the writer has had experience have always been large. The teaching of such a class has usually resolved itself primarily into a problem of accommodation. With facilities for an average class, classes of from forty to fifty have confronted me. To do as efficient teaching as possible under such conditions, the following procedure has been used.

At the beginning of the year the large class is divided into two groups which will be designated as A and B for convenience sake. When the groups have been organized, usually about the second meeting of the class, a preliminary science test is given which embodies questions from every possible source of everyday science. The motive of this test is to determine just how much elementary scientific data the pupil has at his disposal. This test serves also as a basis for pupil classification and guide for the measuring of results obtained.

The work of the year is divided into closely related units or principles, each unit occupying as much time as its importance demands. Physics is arranged on the school program in such a manner that the two sections come at consecutive periods of the day. These periods are from forty to fifty minutes in length. The time of the unit is divided as follows:

The first day is a day of assignment. The work is laid out for them, assignments made in the pupils' reference text and in the reference texts from the science library. The required reading is at least two of the assignments made. The work is carefully assigned and troublesome points made clear by an introductory discussion. If a demonstration is possible it is used as a means to arouse and stimulate interest in the problem at hand. Near the close of the period the assignment of a laboratory exercise,

bearing directly upon the solution of the problem, is made. An effort is made to arouse interest by assigning the exercise in the form of a question; for example, instead of assigning the conventional experiment, "To find the Specific Gravity of A Liquid," such a question as this is placed on the board, "How May a Hydrometer be Constructed? What are some of its practical uses?" Such assignments tend to arouse a spirit of wonder in the pupil and a desire to accomplish. The above is given to group A during the first hour and to group B during the second hour.

On the second day of the unit, group A assembles in the laboratory for the solution of the problem assigned on the previous day. Before the students are allowed to go to work the instructor goes over the laboratory directions carefully and points out any parts from which a difficulty may appear to rise. During the progress of the work, the instructor visits the several working groups, quizzing various ones on fundamental points either of construction, theory or operation. At the close of the hour, time is taken to sum up the data obtained and to draw certain definite conclusions. Group B assembles on the third day of the unit for the same laboratory work that group A had on the second day.

The fourth day of the unit is given over to the regular meeting of the groups at their assigned periods. This meeting takes the form of a class conference rather than a formal recitation. Questions arising from the assigned reading and from the work in the laboratory are brought up and discussed. The instructor keeps in the background as much as possible and attempts to direct the questions and problems which come up in such a manner as to secure the most thorough discussion. These class conferences tend to keep the pupils awake every moment of the period and are found to go a long way toward stimulating interest.

If the fourth day of the unit is not sufficient to clear all problems and complete the discussions, more time is given. The length of the unit depends largely upon the importance of the problem at hand. In this procedure one of the elements which has proven successful is a very elastic program. On the days when problems and points of difficulty are discussed, if the answer can better be found by the pupil he is sent into the laboratory to solve his own problem.

At very frequent intervals a test is given to measure the

abilities which have been developed. These tests are given in several different forms. For example the biographical side of physics is tested by a simple matching test. Laws are readily tested by true-false tests. The range of information may be tested by completion tests, matching tests or association tests. Problem solving ability may be tested by a simple test which includes fundamental problems.

The teacher may relieve himself of considerable burden if the pupils are allowed to score the tests. The students exchange papers, the correct answers to the several questions are rapidly read and the score determined. Before the papers are handed back to the owners, the instructor asks each student for the score on the paper which he holds. These are placed on the blackboard in several columns which represent the distribution of the class scores. When this has been done, the papers are handed back to their owners. In this way the test serves not alone as a test but also as a stimulant to the low pupils. There is, however, a point which is to be guarded against, lest the pupils who stand high be content to rest on their attainment.

Whenever the work in physics is of such a nature as to make project work possible and advisable, the above procedure is varied to meet conditions. For example, in the study of pneumatic appliances the instructor posts on the bulletin board a list of projects and each student is permitted to select the one nearest his interest. The students selecting the same project are then organized and a group leader selected. The work is planned with the help of the instructor and each group proceeds to work out the problems of the project, whether it be the construction of a hydraulic elevator or measuring the suction of a vacuum sweeper. A number of reference text assignments are made, which are required readings. The readings are so selected that every phase of every project is covered. These serve to give the pupil a background when the work of the different groups is presented to the rest of the class.

A definite length of time is given over to the study of the projects and the solution of the problems arising from them. At the conclusion of this time, each group is given about one period to bring its work before the class and make a definite report upon it. Time is given for the class discussion of each project. Each student of every group is required to write up a report of every project in which ten fundamental questions bearing on the project and submitted by the members of the

group which have selected that project, must be answered. These reports are then handed to the members of the respective groups and are looked over by them. If they are satisfactory they are brought to the instructor for approval and credit. If they are unsatisfactory they are turned back for correction.

Besides the work on pneumatic appliances, many parts of the work in physics may be treated in this manner. Parts of Heat, especially the study of modes of heat transfer and heat engines, lend themselves aptly to the project method. Certain parts of Electricity and Light may also be taught in this way.

In the use of this plan of procedure, the several units which go to make up the year's work are bound together by lectures and talks in which an attempt is made to point out to the student the broader governing laws and principles of physics. For example a lecture on the work principle serves to bind the Mechanics of Solids to the Mechanics of Liquids. A lecture on energy and its forms binds Mechanics with Heat and Electricity. A lecture on wave motion binds Heat, Light and Electricity. Frequent use of the stereopticon makes these lectures more interesting and lasting.

PRINTING DOUBLE-WEIGHT PAPERS.

The continuously greater use which is being made of double-weight papers of practically postcard substance for portrait-photographs, inserted without mounting in the popular folders, calls for somewhat greater care in printing, says *The British Journal.* The curl of a fair-sized piece of such paper may easily be such that proper contact over all parts of the negative is not obtained in a printing-frame fitted with the customary rather weak springs, or in a printing-box if hand-application of the pressure-back chances to be done in a careless manner. With some printing-boxes uniform pressure of the back calls for correct manipulation of the handle, and when a thick paper is being used it is quite possible to have faulty contact over part of the negative. In many cases this liability may be readily remedied by thickening the pressure-pad by fixing a stout piece of felt to it, or by laying a piece of felt upon the paper after inserting a fresh piece of the latter. Of course, a precaution such as this will be taken by the experienced printer, especially if he has been accustomed to handle carbon-tissue, the pronounced curl of which calls for the frames of extra solid construction provided with strong springs fitted to hinged cross-bars. The fact that exposure of papers is often placed in the hands of comparatively unskilled assistants is no doubt responsible for defects of definition in prints which have been submitted to us with the suggestion that the lens was at fault. That such was not the case should have been evident from the fact that the unsharpness occurred in different parts of the subject from the same negative.—[*Photo-Era.*

THE USES OF ALGEBRA IN STUDY AND READING.

By Edward L. Thorndike and Ella Woodyard,
Institute of Educational Research, Teachers College, Columbia University, New York City.

(Continued from May.)

The Use of Algebra and Geometry Shown by an Inventory of the Encyclopedia Britannica.

To arrive at a notion of how far Algebra has penetrated into the intellectual and practical life of men of intelligence and achievement comparable to that of high-school graduates, an examination of the Encyclopedia Britannica has been made, noting all references to mathematics beyond arithmetic. The first two hundred pages of each volume from I to XXVIII have been read and the mathematical references collected.

Table 3 gives the facts as found:

Table 3. Encyclopedia Counts.

	Number of Articles Concerned	Number Linear Inches Space Utilized
Mathematical Definitions	12	22
Long Articles with Slight Mathematics	7	3,714
Requiring Vocabulary of Geometric Shapes:		
Description of Crystals	39	874
Shapes of bldgs, land, etc.	60	2,301
Other use of Terms Indicating Geometric Shapes	68	4,606
Biographies of Mathematicians	32	663
Requiring Algebra Only:		
Graph	5	375
Formula	2	123
Requiring more than Elementary Algebra	44	7,063
Total Mathematics Usage	269	19,741
Total Examined	7,551	106,400

A further analysis may be illuminating.

The twelve articles listed under "Mathematical Definitions" are: Abscissa, Angle, Angulate, Anthelion, Axiom, Axis, Azimuth, Correspondence, Diagonal, Diameter, Gnomon, Ordinate. General intelligence, rather than knowledge of mathematics, is required to understand these definitions.

The seven articles which are listed under the head of "Long Articles with Slight Mathematics" are: Bacteriology, Egypt, Glass, Harmony, Medical Education, Mendelism, Respiratory System. The person who knew no high school mathematics would be handicapped in reading not more than twenty-five linear inches of the 3,714 inches used in these articles. He would find the words conical, plane, parallel, angle, cylindrical, spheri-

cal, ellipsoid, rectangular, abscissae, ordinates, of whose meanings he would be ignorant or doubtful, and he would be at a loss to interpret the following five formulae:

$$V = (nd-1)/(c-F)$$

$$v/(V+v) = p/100$$

$$V = v(100-p)/p$$

$$ab^2 = AB^2+(Bb-Aa)^2+2AB(Bb-Aa) \cos x$$

$$c^1d^{1\,2} = AB^2+(Ac^1-Ba^1)^2-2AB(Ac^1-Bd^1) \cos x$$

In addition he would find one statistical graph of meager meaning and would be doubtful concerning the exact idea conveyed by this sentence: "And hence the enharmonic circle of fifths is a conception of musical harmony by which infinity is rationalized and avoided, just as some modern mathematicians are trying to rationalize the infinity of space by a non-Euclidean space so curved in the fourth dimension as to return upon itself." Otherwise, he probably could read all the articles with as much profit as if he were skilled in mathematical lore.

Again the one hundred sixty-seven articles listed under "Requiring Vocabulary of Geometric Shapes" make small demand upon knowledge of mathematics. The thirty-nine of these listed under "Description of Crystals" contain usages of the technical terms describing the shapes in which crystals of various substances occur and are illustrated and explained in texts dealing with these subjects. This nomenclature originally was taken from solid geometry but it has become a part of the special equipment of the student of those branches of Geology which utilize it, and may reasonably be expected to be acquired there by one who needs it. The second division, "Shapes of Buildings, Land, etc.," includes such terms as rectangular, rhombic, quadrilateral, conical, cylindrical, triangular, trapezoidal, spherical, square, octagonal, hexagonal, quadrangle, as these are applied to grounds, towers, tunnels, and the like. The third division "Other Use of Terms. Indicating Geometric Shapes" is a similar usage of terms as applied to plants, water systems, tools, cameras, explosives, glaciers, harps, ivory, labyrinths, pencils, perfumery, and the like. The person who had not studied geometry might find his comprehension of the articles less easy and accurate than his more favored friend who had studied geometry in school, but he would probably not suffer greatly.

The thirty-two biographies of mathematicians do not use any mathematics in the articles, but they list the achievements

and books of their subjects and therefore probably would have slight meaning for the person untrained in mathematics.

The seven articles appearing under the head "Requiring Algebra Only," are: Animal Heat, Dew, Electricity Supply, Hydrozoa and Sunshine (which are illustrated by graphs using the terms abscissae and ordinates in their explanation), and Anemometer and Hearing, in the latter of which occur these formulae:

$$
\begin{aligned}
P &= .0005^2 \text{ that is } .0005v^2 \\
ut_2 &= 256 \\
ut_3 &= 512 \\
ut_6 &= 2{,}048 \\
re_6 &= 2{,}304 \\
sol_6 &= 3{,}076 \\
si_6 &= 3{,}840
\end{aligned}
$$

The reader ignorant of algebra would be handicapped in these articles to the extent to which these are an essential part of the explanation.

There remain, from the 7,551 articles occupying 106,400 linear inches of printed matter, forty-four articles for the understanding of which more than high school mathematics is required.

Table 4 gives a detailed analysis of these articles. A check mark in any column indicates a need of the subject at the head of that column for the comprehension of the article. For instance, "Calorimetry" requires Algebra beyond elementary and the calculus; "Diagram" needs Geometry, Analytics and Projective Geometry for its complete mastery.

Assuming that the importance of articles is roughly proportioned to their length the following per cents are interesting. The articles using mathematics beyond arithmetic in any form are 3.57 per cent of the total number of articles, but they occupy 18.55 per cent of the total space. If from these we discard the long articles in which very slight reference to mathematics occurs the articles remaining are 3.47 per cent of the total number of articles, but use 15.06 per cent of the space. The articles which call for a geometric vocabulary, though not necessarily geometric knowledge, comprise 2.21 per cent of the total number and use 7.31 per cent of the total space. If only those articles using elementary algebra and advanced mathematics be considered, the per cent of the total number of articles is .68 and of the space 7.11. Those articles which utilize advanced mathematics are .58 per cent of the total number of articles, but require 6.64 per cent of the total space.

These facts suggest the following conclusions:

TABLE 4.

Mathematics required to read:	Adv. Alg.	Geom.	Trig.	Anal.	Calc.	Other Math.
Aberration	√	√	√	√	√	Method of Least Square
Absorption of light	√					
Accumulator	√					
Anomaly						Astronomy
Calibration			√			Method of Least Squares
Calorimetry	√				√	
Continued Fractions	√		√		√	
Density	√				√	
Determinant	√			√	√	
Diagram		√		√		Projective Geometry
Dial		√	√			Astronomy
Elasticity	√	√	√	√	√	
Electrical Machine	√	√				
Electricity	√	√	√		√	
Heat	√	√			√	
Hydraulics	√	√	√	√	√	Method of Least Squares
Hydromechanics	√	√	√	√	√	
Hydrometer		√				
Hyperbola		√		√		
Lapidary		√				
Lubrication	√				√	
Mensuration	√	√	√	√	√	
Ohmmeter		√	√			
Orbit	√	√		√		Astronomy
Order				√	√	Differential Equations
Ordnance	√	√	√			
Perpetual Motion		√				
Polygon	√	√	√			
Polygonal Numbers	√	√				
Polyhedral Numbers	√	√				
Polyhedron	√	√	√			
Porism		√				
Reflection of Light	√	√				
Refraction of Light	√	√	√			
Sights		√	√			
Sun	√	√	√	√		Astronomy
Surface	√	√	√	√	√	
Surveying	√	√	√	√	√	
Traction		√		√		
Transformers	√	√	√	√	√	Standard Deviation
Transit Circle	√	√	√			Astronomy
Vision	√	√	√	√		

(1) The parts of elementary algebra that have made a place for themselves in the reading matter of the man who seeks information upon topics of widespread interest are the graph—particularly the statistical graph—and the formula.

(2) Elementary algebra is not sufficient to enable one to read encyclopedia articles dealing with technical topics in physics, engineering, astronomy, chemistry, mathematics and allied subjects; but rather, speaking in general, one must have acquaintance with the mathematics ordinarily presented to the

student in courses to be pursued from three to five or more years subsequent to the year of elementary algebra.

(3) The importance of mathematics to an understanding of subjects of general interest is much greater than the frequency of its use since the ratio of about 1 to 10 is maintained between the per cent of the number of articles and the per cent of space they occupy.

There are certain inferences from the foregoing that seem worthy of consideration in connection with the curriculum in first year algebra.

(1) For utilitarian values in the first year of algebra one must pay much attention to the formula and to the statistical graph.

(2) The student whose aptitudes and capacities will probably lead him into any one of a large number of fields of advanced study such as physics, engineering, psychology, chemistry, education, electricity, economics, aeronautics, social sciences, ballistics, navigation, etc., should have preparatory work not merely in algebra but in many other branches of mathematics to which rigorous algebra is the necessary antecedent and tool.

In comparison with careless statements implying that a knowledge of all that is taught in the usual course in elementary algebra is of frequent use in the study of science, the facts which have been presented here may seem to reduce the utility of algebra to a small matter. Similar analyses of text books and of the Britannica with reference to other high-school subjects would, however, show that algebra was at or near the top in this respect. Since further science in general is steadily becoming more quantitative, the utility of ability to read formulae and graphs is increasing. Consider for example the prominence of frequency curves and correlations in biology, psychology, sociology and education today, remembering that thirty years ago they were almost unknown there.

Algebra is a useful subject, but its utility varies enormously. Very few, if any, cases appeared in all the text books examined or in the 5000 pages of Britannica where ability to factor a^3-b^3 or a^3+b^3 was demanded. There were few, if any, cases where the ability to factor a^2-b^2 was demanded. Algebraic abilities form a series of diminishing utility, beginning with reading formulae and graphs of the relation of one variable to another, and ending with short-cut methods of division by knowledge of special identities.

The mere knowledge of the language of algebra has more

utility than educators have thought, while skill in computing has less. Educators are prone to think it folly to learn algebraic symbols at all if you don't compute with them. They forget that we have to read them, and perhaps twice for every once that we compute with them. The knowledge of and ability to use formulae in solving quadratics, answering problems about progressions, and determining coefficients and exponents in the binomial expression which figure so largely in school examinations are toward the low end for utility.

In general, we may divide this continuous series into five groups or sections.

Section 1 includes:

The notion of symbolism, ability to "let . . . = the number of . . ."

Ability to read simple formulae, including knowledge of positive integral exponents, of $\sqrt[2]{a}$ or $a^{1/2}$, $\sqrt[3]{a}$ or $a^{1/3}$, of single parenthesis, and of the omission of the $\times$ sign and of 1 as coefficient.

Ability to evaluate and solve such formulae, including the interpretation of negative numbers as answers, when the unknown forms one member of the equation.

Ability to read graphs of the relation of one variable to another in the $++$ quadrant, when the nature of each variable is understood.

Section 1 seems worth requiring of all students in grade 9 if anything is worth requiring of them at all, and if they have not learned its content previously in arithmetic.

Section 2 includes:

The ability to read formulae involving a parenthesis within a parenthesis and complex fractions. This involves learning algebraic addition and subtraction, algebraic multiplication and division by monomials, and certain elementary facts about radicals and surds.

The ability to transform formulae (after evaluation) where the desired number has a coefficient or is found in a denominator, or appears twice, or is only one term of one member of the equation into formulae where it appears alone as one member. The ability to do so before evaluation, provided no division of a polynomial by a polynomial is required.

Section 3 includes:

The elementary algebra of the relation of one variable to another, including graphic presentations.

The solution by linear and quadratic equations of genuine problems for which such solutions are desirable.

Simultaneous linear equations.

The elementary facts concerning surfaces of frequency, central tendencies, and variability or dispersion around a central tendency.

The use of logarithms, tables of powers, roots and reciprocals, the slide rule and other means of facilitating computation.

Approximations and significant figures.

Section 4 includes:

Negative and fractional exponents.

The general treatment of radicals (probably without imaginary numbers).

Simultaneous equations. One linear, one quadradic.

Elementary theorems in probability.

The exponential curve and the theory of logarithms.

Correlation.

Training with general formulae, especially the binomial theorem and the progressions.

Computations rarely used, such as multiplication and division by polynomials and factorization of polynomials.

Section 5 includes:

Simultaneous equations, both quadratic.

Literal equations other than useful formulae.

Imaginary numbers.

Equations higher than the second degree.

Fitting curves to observations.

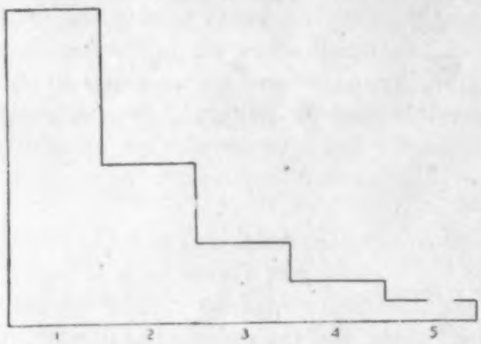
It is, of course, the case that these sections are not clean-cut, but overlap somewhat, certain features of a topic being more useful and others less useful than the general place assigned to the topics would indicate.

The abilities in Section 1, which can be acquired in a couple of weeks of the course, are probably many times as useful[7] to the general run of high school pupils as all the abilities of Section 4, on which twelve weeks or more are often spent. If we had sufficient knowledge to measure the utility per hour of time spent we should, in fact, probably find it diminishing at least as rapidly as is shown on page 521.

The fact of diminishing returns in the way of direct practical utility probably characterizes many of the high school subjects.

[7]"Useful" and "utility" are used here as hitherto in this article of the direct practical utilities in contrast to utility as training, but including utility as preparation for other studies.

The awareness that nature is regular, lawful and predictable, and a few chosen facts about mechanics, heat hydrostatics and electricity, teachable in a month, would probably outweigh for utility to the general run of high school pupils as they live today, what they might learn in the next two months, or in the five thereafter, or in an entire second year. The acquisition of a vocabulary of five hundred French words in fifty hours and such



common facts and laws of French grammar as could be learned in another fifty hours would outweigh, for utility to the general run of high school pupils as they live today, what they would acquire in the 500 hours spent in extending the vocabulary from 10,000 to 12,500, and in acquiring the mastery of subtle matters of form and syntax.

With certain individuals, the case may be very different. The last thousand hours of study which makes him the world's authority on some field of mathematics may be for a certain person the most useful of all. It may for example quadruple his service to the world and double his salary. It is useful for the world not only to have many persons competent in certain often used abilities but also to have a few persons competent in specialties. If a high-school pupil is cut out by nature to be a scholar and discoverer in mathematics, the chief utilities of the course in algebra for that pupil are not those which we have been discussing but the amount of force with which the course in algebra helps him on toward being a mathematician and advancing the world's knowledge.

Actual, Possible, and Desirable Uses of Algebra.

We find in the case of arithmetic that people often do not use it when it would be to their advantage to do so, because they have not mastered it. A woman seeing "7 5/8 lb. roast beef, $2.67" may spend five minutes in telephoning the butcher to

ask how much the roast was per pound, because she cannot readily divide by a fraction. Many people waste much time in dividing by long numbers when it is much easier to multiply by their reciprocals. The same may be true of algebra. Writers may use long and clumsy verbal descriptions because they lack the ability and habit of framing a formula to describe a state of affairs or relation. Very little use of algebra is made by accountants, but this may be due in part to traditions from the bookkeeping of the small shop whence scientific accounting developed, rather than to essential needs and desirabilities.

It is even possible that the writers of the textbooks which we surveyed occasionally failed to use algebra in ways that would have been desirable, because they lacked the required knowledge or skill.

THE VALUES OF ALGEBRAIC ABILITIES FOR DIRECT USEFULNESS AND FOR CULTURE.

There are notable discrepancies between the serial order in the four sections above and the serial order in which the abilities should probably be put in respect to their value for what we vaguely call culture.

Negative and fractional exponents, which represent a system which is in mathematics what a master poem or painting is in art, or what the law of the conservation of energy is in empirical science, rank very low for direct usefulness. The use of logarithms, tables, and slide rule rank in the utility series along with the conception that a relation between two variables may be expressed as the line made by a moving point, or by the equation telling the location of this point with respect to a defined coordinate system. The former would usually be regarded in respect to culture, as like learning to use a crowbar, or take the elevator; the latter is a conception comparable by its unity, range, and power to any epic poem or symphony.

In many important features, however, there is agreement. The general lesson of algebraic symbolism ranks high in both series. Elaborate manipulations and simplifications by canny use of certain combinations and factorizations rank low in both. The study of a variable quantity, expressed by a surface of frequency, and measured by describing the form of that surface and reporting its central value and variability would be left by raters for cultural value not far from its place for usefulness. The progressions as ordinarily taught are about as devoid of culture as of utility.[8]

[8]If they are used as introductions to and parts of more general truths, as by Nunn, they gain notably in cultural value.

THE RÔLE OF MEMORY IN ALGEBRA I.

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Chapter I.—Thought Processes in Algebra.

Part I.—An Analysis of Algebra.

The Problem.

Before attempting to discuss the rôle of memory in algebra, it will be well to determine, with considerable definiteness, just what algebra is, in what respects it differs from the other branches of elementary mathematics, why it is studied, what its elemental characteristics and activities are, and the things which must be kept in mind and aimed at as objectives in its teaching. Equally important is a resumé of the different factors, types and aspects of memory, considered both psychologically and from the point of view of pedagogic application to the various learning processes. With these two general phases of the subject in hand, we shall be in a better position intelligently to discuss, in some detail, the rôle of memory in algebra. To this end we shall attempt, in the first two major divisions of this discussion, to set out the defining mental activities of algebra, or the essential

things that make algebra what it is, and to bring to light some different types and aspects of memory. So far as circumstances have permitted, the attempt has been made to canvass the field of significant and representative literature, in order to get a comparison of the attitudes of different significant writers, and thus to avoid a narrow and biased point of view which might lead to the drawing of false conclusions and inferences.

Defining Algebra.

It is difficult—if not impossible—to define algebra in so rigorous a way, as to set it off completely as a branch of science, wholly apart from the other mathematical branches. Mathematical matter and method are in general too intimately interwoven to admit of any complete distribution into intensely exclusive domains. In particular, there is a good deal of overlapping between algebra and geometry, as well as between algebra and arithmetic. DesCartes showed the relation of algebra and geometry, and the inter-relation of algebra, geometry and arithmetic is being brought out in a very pronounced way in the present movement toward correlated or unified mathematics. Attempts have been made to define algebra, but the definitions enunciated by different writers are not always in agreement. Comte defined it as the resolution of equations, differentiating it from arithmetic by defining that science as the determination of values of functions. He concludes that "Algebra is the calculus of functions, and arithmetic the calculus of values."[1] D'Alembert called it "a generalized or universal arithmetic, or the science of calculating magnitudes considered generally."[2] A more comprehensive definition is that of Dauge: "Algebra has for its object the generalizing of the solutions of problems relating to the computation of magnitudes, and of studying the compositions and transformations of formulae to which this generalization leads."[3] We readily see the difficulty of giving a definition which is at the same time inclusive and exclusive, and, as Nunn says in his "Teaching of Algebra," the discussion may be carried to a point of useless academic argument. It is rather through an analysis of the subject than by means of a hard and fast definition that we shall get an adequate notion of its scope and content, and this analysis shall be our first problem.

[1] D. E. Smith, *Teaching of Elementary Mathematics*, p. 162.
[2] *ibid.*, p. 163.
[3] *ibid.*

Judd on the Character of Algebra.

Professor C. H. Judd gives us perhaps as helpful a statement as to the psychological aspect of algebra as can be found anywhere. Viewing it from the standpoint of the psychologist, he says:

". . . it is of the highest importance that we distinguish between measurement and number combinations. Algebra is a science which studies the laws of number recombination without any reference to standards of measurement. The student who has been studying weights and measures in the upper grades of the elementary school comes into algebra, and finds no tables of weights and measures. He finds some of the familiar forms of combination which he used in arithmetic, but these combinations are freed, as far as possible, in algebra, from direct reference to any particular standards of measurement. Algebra does not measure; it establishes and expounds laws of combination and recombination. It is an abstract science of the laws of mathematical combination. It is not a final chapter of the ordinary arithmetic; such chapters invariably deal with applications of mathematical laws to complex measurement."[4]

The foregoing quotation brings to light very forcefully what is evidently the case: namely, that while algebra has many characteristics which make it somewhat comparable to arithmetic, still there is an essential and fundamental difference in that algebra is *entirely* a science of abstraction. This does not mean that abstract thought has no function in arithmetic, for the testimony of all writers on the psychology of arithmetic is to the fact that abstraction is the basic factor in building up the number concept. The difference is that the abstract number concept having been developed, it is applied, in arithmetic, to measurement and actual enumeration, and in this way each symbol comes to have a specific and invariable significance. Algebraic symbols on the other hand, remain forever abstract, forever relational, forever dependent, their actual significance varying from time to time and from case to case.

Of course, the mathematical laws that obtain in arithmetic are universal, and it follows that algebraic symbols can be manipulated according to these laws, in the same way as number symbols. The algebraic formula, as Judd points out,[5] is simply a means or device for stripping the process of all content; of making it essentially and entirely symbolic and abstract. The

[4] *Psychology of High School Subjects*, p. 95.
[5] *ibid.*

value accruing to such a form of reasoning is evident. Without it, we should be without the means of analyzing very many particularized cases, and of grouping, classifying and manipulating particularized cases under comprehensive generalized forms.

Thus we see that abstraction is the characteristic feature differentiating algebra from arithmetic. Since we are to be concerned with certain psychological aspects of algebra, it is believed that it would be well, at this time, to look somewhat more closely into the essential nature of abstraction. It is not our wish to speculate on this. We shall limit ourselves, therefore, to a review of the salient points in Dr. Judd's further excellent treatment of the matter in his chapter on number and abstraction.

The Psychology of Abstraction.[6]

Abstraction is a selective form of thought. The process which takes place in the mind, in the abstraction of an idea is not unlike what takes place in the coördinated working of the mind and the body in habituating or automatizing some physical act, although there are certain differences which render the possible results of the two processes not entirely comparable. In abstracting an idea it is necessary to focus the attention on one aspect of the matter in hand, while the other aspects are disregarded. In automatizing an act we find that it is necessary consciously to inhibit certain tendencies at first, because the coördination of the muscles has not been learned. A state of diffusion of activity exists, but by conscious inhibition of all but the essential movements, and by continued practice, a complete coördination and automatization can at length be effected, so that the act can be carried on without the slightest attention being paid to it. A very large part of our acts are of this habitual nature, and the economy of time and effort and the extent to which the attention can be freed for other things is astonishingly large.

In the same way, when we try to abstract a single idea, to isolate it from the many irrelevant associations to which we have been accustomed to relate it, we find that it is necessary to inhibit these irrelevant associations, and to pay attention closely and constantly and consciously to the one aspect with which we are directly concerned. Thus in the development of the number concept, objects are used as tallies and counters. Counting and

[*Note:* In this discussion, no claim is made to originality of treatment nor to original contribution. All that has been attempted is to organize the exposition of the author cited into a concise, pertinent discussion of the topic. Full acknowledgment is made of the suggestion, by this chapter, of all points in this discussion. C. H. B.]

[6] cf. Judd. C. H., op. cit. pp. 95-122.

tallying are used as means of expressing quantative relationships, but they in themselves do not produce an abstract concept of number. To get this one must pay attention not to the ordinal sequence nor to the one-to-one correspondence, but to the aspect of multiplicity and must disregard so far as possible, all other aspects.

Words and symbols are the chief instruments of abstraction. They are means of expressing ideas, and of aiding in the analysis of situations. In that they obviate the necessity for vivid sensory comparison and discrimination and exhaustive mental recall, they are economical of time and mental energy. By the elimination of all concrete content from the symbols, it is possible still to manipulate them according to the laws of mathematical operation, and at the same time to give all the attention, the operation, avoiding, in this way, the disturbing quantative element. Since symbols are representative experiences which are substituted for direct experiences, they facilitate generalization and classification. We quote the following from Judd[7] to show how the process of abstraction is carried on:

"The first stage of abstraction is to neglect certain of the facts of the environment, and to concentrate attention on the others; the second stage of abstraction is that in which we substitute products of our thought for real experiences, and by using these products of our thought we carry on more rapidly and efficiently all sorts of complex comparisons and discriminations."

Nunn on the Fundamental Activities.

An interesting discussion of the essential nature of algebra is found in T. P. Nunn's description of the elements which it embodies.[8] They are four in number: (a) analysis, (b) direct use of symbolism, (c) extended use of symbolism, and (d) manipulation of symbols. The first of these is given the place of most prominence, as the most fundamental characteristic. By analysis is meant the *process* whereby abstraction and generalization are accomplished. Though the analysis of particular numerical examples may easily lead to a generalization or rule, the two processes are not identical, nor is analysis identical with the solution of a problem. In solving a problem, the numerical properties are of great importance, while in analysis, as such, these must be disregarded, and prime consideration given to the *process*. This, having been abstracted from its limiting number considera-

[7] p. 100.
[8] *Teaching of Algebra (incl. Trigonometry)* pp. 1-15.

tions, the generalized statement of the process may be given as a rule of procedure. It is pointed out that mathematical generalizations differ, as a rule, from generalizations in other sciences, in that a rule may be abstracted from a single case, while in biology, for example, it can be stated with any degree of certainty only after the most elaborate observation of a multitude of cases. The difference is that the one depends upon deductive reasoning, or abstract analysis, while the other must be made by inductive reasoning involving observation of many cases since there are no immediate means for separating it from its concrete features. To be sure, there are certain mathematical generalizations which must be arrived at inductively, and the importance of such generalizations is not to be minimized. Such generalizations, however, cannot be pronounced invincible until they are verified deductively. Consequently a rule based upon well-grounded analysis is more certain, and therefore more valuable in reasoning, than one based only on observation.

Symbolism is needed to aid in the expression of the analysis of a situation. Without some sort of symbolism there could be no generalization. As was brought out in the discussion of the psychology of abstraction, language is only a symbolic or conventional way of expressing and communicating ideas; words are symbols and we use them to enunciate our generalized rules. The use of language in mathematical analysis, however, would result in great prolixity and circumlocution, and probably in vagueness of meaning. This will be realized when it is remembered that the *process of analysis* is concerned with a specific case rather than with generalities. To overcome this difficulty, a more compendious symbolism having particular meaning and ambiguous reference has been evolved. These symbols consist generally (a) of arbitrarily but universally accepted signs of mathematical operation, and (b) of the use of letters of the alphabet to represent numerical quantities. These form a concise and intelligible symbolism which makes the analysis and the expression of results more easily apprehended and for this reason it is given second place among the fundamental elements of algebra.

Our author[9] is so deeply impressed with the value of symbolism that he would extend it to other spheres of thought and have an indefinite number of algebras. He says: "Wherever there is a field for inquiry of a certain type, an algebra might be invented to facilitate that inquiry."[10] Thus there might be de-

[9] Nunn.
[10] op. cit. p. 5.

veloped a chemical algebra, a physical algebra, a biological algebra, an historical algebra, etc. The aim would be to facilitate investigation and statement by replacing language with symbolism; by making symbols the mere conventional substitutes for ideas. The chemical formula, the hypothetical name in a legal case are but examples of what might be done in handling these generalized notions or chemical and legal variables.

The third element, the *extended* use of symbolism,[11] means simply extending the symbolism to cover further generalized cases not originally included. For example, the analysis of the method for finding the area of a rectangle *with integral dimensions* results in the formula $A = l \times w$. This, having been arrived at by analysis, must hold for the area of any rectangle; hence it can be extended to include rectangles that have fractional dimensions.

Symbols not only facilitate the expression and grasp of thought, but can be handled as numbers. Vieta said they may be "exercised." This property is the fourth fundamental element of algebra. It has two chief uses: (a) It is a generalized expression of particular arithmetical procedure; (b) by manipulating letters as if they were numbers, we can predict with certainty the typical form of the arithmetical result.

"We may summarize this discussion by saying that from one statement expressed in algebraic symbols, it is possible to deduce, merely by manipulating the symbols in accordance with the laws of arithmetic, an indefinite number of statements, each of which will be true if the original statement is true."[12]

The Function Idea.

Professor D. E. Smith[13] gives still another characterization of the essential nature of algebra. He stresses the idea of the *function* as the dominating element in algebraic thought and procedure. He maintains that the function is not only the first and fundamental idea throughout, and the essence of all algebraic thought and operation, but also that it is an easy one to start with. The idea of the function includes the solution of equations and runs throughout all higher forms of analysis. Because too often it is not stressed and elaborated early in the course, difficulties inevitably follow later on.

Summary of Part I.

Bringing together, then, the points we have noted, we find that

[11] *ibid.* pp. 10-12.
[12] Nunn. op. cit. p. 14.
[13] op. cit. pp. 163-165 (cf. ref. p. 2 this paper).

algebra is a science which is concerned purely with the operation of the laws of mathematical combination and recombination, and has no concern with standards of measurement; that it has certain characteristics in common with arithmetic and geometry but differs from either of these in that it is essentially a purely abstract science. We find that abstraction is a process of selective thought, requiring for its consummation concentration of the attention on one particular aspect of the subject under consideration and the disregarding of all other aspects; and that words and symbols are the chief instruments of abstraction. We find that algebraic operations are concerned chiefly with some consideration of the function, and that they are carried on by means of the processes of analysis and the use and manipulation of symbols. These points bring out the fundamental psychological characteristics of the science. We shall now turn our attention to the nature of the thinking involved.

Part II.—Types of Thinking.

Freeman on Problem-Solving or Thinking.

Professor F. N. Freeman[14] defines problem-solving, or thinking as "setting up a conscious goal, the attainment of which presents difficulties, and the discovery and recognition of that relationship between the elements of the problem which will lead to its solution." The rational type of thinking referred to here is evidently the sort that is essential to algebraic work. In his chapter on problem-solving,[15] Professor Freeman points out several important aspects of reasoning which we shall take occasion here to enumerate and to comment upon briefly. We quote, below, the headings of some of the topics in this chapter:

"The distinguishing feature is the clear recognition of a problem and of its solution."

"Problem-solving depends upon the grasp of relationships which contribute to a solution.

Clearly, then, problem solving involves both the processes of analytical and synthetic thinking. Analysis of the problems is indispensable, for it is only by this means that a *clear* recognition of the elements of the situation is to be attained. Moreover, since problem-solving depends upon a grasp of relationships existing among these elements, association of the elements is implied, and this association, when properly made, is nothing more nor less than a synthetic building up of the steps that contribute to the solution. When we consciously arrange these

[14] *How Children Learn*, p. 216.

steps in an orderly fashion, we perform an act of reasoning in which are included both deductive and inductive thought. Each of these involves the orderly association of certain elements of a situation, and both contribute to its solution, though in different ways. Inductive reasoning is an attempt to make a generalization from the observation of certain facts or characteristics. Deductive reasoning, on the other hand, begins with a general rule, and endeavors to say what the results will be in a particular case coming under this rule. Naturally induction finds its field of greatest service in new and untried fields of investigation, while deduction functions chiefly in the realm of formulated rules and laws. The whole upshot of this discussion of problem-solving is that efficient rational thinking is characterized by systematic procedure in the analysis of the problem into its elements, and in the synthetic arrangement of steps in an orderly, logical sequence, leading to the solution.

Specific Types of Thinking.[16]

We may go further into the matter, however, and inquire more carefully into some of the more directly specific types of thinking that must be taken into account in the actual teaching of algebra. Here may be mentioned some twelve fairly distinct types of thought. Possibly the list might be extended, but our efforts in this direction have resulted mainly in hair-splitting distinctions that contributed little or nothing of value. The twelve types referred to are listed below with such explanatory or suggestive comment as seems appropriate.

1—*The Conceptual Type.* Its purpose is to develop and clarify fundamental ideas or concepts. This consideration will be a governing factor in classroom procedure. In order to see the purpose of a process, the student must go slowly and carefully rather than to strive especially for speed. In our opinion speed alone is not a good criterion for algebraic ability, and while it is often desirable, there are also times when the aim to attain speed should give place to the effort carefully to develop clear notions, and it is the conceptual type of thinking that must predominate at such times. Many methods of presentation, such as illustration, comparison, graphing, description, explanation, etc., can be used to advantage, for the clarity of concepts is dependent in a considerable degree upon wealth of experience.

[15] op. cit.

[16] Grateful acknowledgement is made of the special help given by Professor Myers in connection with this section of the discussion. C. H. B.

2—*The Expressional Type.* Here is involved a comprehensive clarity of thought which should result in the ready translation of a concept into words. Learning and gaining facility in the unemotional language and symbolism of the specific science in hand call for this type of thought. The mysterious power of recognizing the abstract symbol as sufficiently representing the concrete thing symbolized, of seeing and apprehending the general in the particular, is present in this type of thinking.

3—*The Associational Type.* This type is demanded in the attempt to show the reference of a general concept to particular cases falling under it, and vice versa. The association may be the making clear of the relation between general (type) and specific equations, as, for example, is brought out in substituting numerical for literal coefficients and exponents. Since the thing to be emphasized is the relation of the general to the particular, all cases involving general formulas require this associational type of thinking.

4—*The Assimilation Type.* The purpose here is to keep at a thing even after the mere threshold of understanding and memory has been passed; so to fix it in the mind that its recall, interpretation and application will remain with one; to get more than a fleeting hold of it. This necessitates repetition, but a repetition that differs from mere drill. The thing must be met in different situations, and be seen in all its fundamental aspects. A careful, thorough understanding and rationalization, rather than automatization, should be the aim; and to insure the ability to get one's bearings in a new situation, more than a single exposure will be necessary. With reference to this, De Garmo[17] says: "It is, therefore, the first great function of the teacher to prepare the way for . . . efficient assimilation of that knowledge which the study hour or the recitation period is to furnish."

5—*The Generalization Type.* Generalization is one of the best tests of assimilation. It may consist (a) of having the students make formulas from verbal statements or from observation of existing relations, or (b) of having them produce other formulas from those already known or assumed. The situation may be presented in any of its phases. It is the type of mental activity used in "setting up" the formula, or equation, or relation, in the first instance.

6—*The Reasoning Type.* By this is meant an attempt to get

[17] *Essentials of method*, p. 32.

hold of the principles of some form of reasoning (as, for example, reasoning by deduction, analogy or reductio ad absurdum) and consciously to apply these principles to the solution of the problem in hand.

7—*The Drill Type.* Though closely associated with the assimilation type, the drill type of thinking has a different purpose: that of automatization. Its aim is rather to convert thinking into reflex action and seeks habit formation. Its type of thinking is that of habit formation. It is questionable whether it has much justification in connection with algebra. Many interesting questions might be raised relative to the use of drill in algebra, as to its mental process and effect, the attitude of the class toward it, and its value as a means of giving an organized and flexible grasp of facts. It is to be feared that drill procedure in class work is very often carried too far in the attempt to cover up other deficiencies in the teaching.

There are two other types of thinking which bear a somewhat close relation to the assimilation type. These are the 8th and 9th types in our list, and we shall call them respectively the *Review Type* and the *Test Type*. Thinking of the *Review Type* occurs in the attempt to organize and classify experiences; of the *Test Type*, in drawing upon the store of experiences which have been assimilated, and attempting to adjust and arrange them in an appropriate fashion, to meet the needs of a new situation. It is a selective type of mental activity.

A type of thinking which is certainly involved in the teaching and solution of certain kinds of algebraic problems and the performance of many fundamental operations we might call the Mechanical or Routine Type. As a matter of fact, it is more a type of reaction than of thinking, and for this reason, though we refer to it here, it is not included in our list. In his highly perfected technique of teaching verbal problems, Mr. E. R. Breslich[18] makes use of this routine type of reaction. It involves the following of a set or formulated plan of attack, which, having been worked out for a particular type of problem, can thereafter be followed automatically. The acquisition of this type of reaction involves association, generalization and assimilation to a very high degree.

10—*The Application Type.* This is the form of thinking required in translating a mechanical law into mathematical form (i. e. giving a statement of the equation for the law.) In this

[18] Of University High School; University of Chicago School of Education.

respect it bears a very close relation to the *Expressional Type* and to the *Generalization Type*. The equation will reveal the nature of the law, and verification can be made by substituting certain values found by actual measurement. This type of thinking involves four steps: (a) Association of mathematical with non-mathematical ideas, (b) the association of mathematical relations, (e. g., equations or formulas), (c) solving the equations, and (d) interpreting and checking the results. Application is one of the powerful incentives to mathematical study.

11—*The Research Type.* This type is rarely met with in high school algebra, except occasionally in working original problems. It involves the following technique: (a) Determine a definite objective; (b) analyze with a view to finding a point and method of attack; (c) check up and verify from time to time during the process; (d) know when the problem is solved; (e) check and prove results.

12—*Appreciation Type.* This type of thought involves an understanding of mathematical activity and an enjoyment in the contemplation of what has been done by great mathematicians, and of what is being done in the realms of both pure and applied mathematics today. It is a result of the fascination of the science, and is one of the greatest incentives to its study.

Conclusion.

The various types of mental activities and attitudes enumerated above unavoidably overlap to a certain extent, and no claim is made for complete segregation. This would hardly be possible. It is believed, however, that they set forth the main characteristic modes of reaction to various algebraic situations, and for the purpose of this paper, this will suffice. With this resume we shall conclude the first chapter. We have analyzed the nature of algebra and have set forth its essential characteristics and the types of thinking which it may involve. This was prerequisite to an intelligent discussion of the role which memory plays in algebraic thought, and this relation will be taken up in a later chapter.

End of Chapter I.

(*To be continued.*)

THE PSYCHOLOGY OF LABORATORY SCIENCE.

By Nathan A. Harvey,
Ypsilanti, Michigan.

I have wanted, for twenty years, to write a paper on the "Psychology of Laboratory Science." The idea has lain fallow in my mind throughout all that time. The principal qualification I had for writing it was about sixteen years of laboratory teaching, principally zoology, but somewhat also of botany physics and chemistry. I have had reason to congratulate myself frequently upon the advantages that my teaching of science has afforded me in my teaching of elementary psychology for the past eighteen years.

Not very much has been done in the measurement of laboratory products since the development of the measurement idea in education, and the results of laboratory teaching have not been sufficiently analyzed. Mayman has reported in the Journal of Educational Psychology the result of an experiment on the relative amounts learned by the laboratory, textbook, and lecture methods. Stewart has proposed a plan for measuring the value of laboratory experiments in Physics (School Science and Mathematics). Judd has contributed a volume on the Psychology of the High School Subjects, but the laboratory work has not been very satisfactorily treated. Parker has discussed the subject with conclusions rather unfavorable to the laboratory.

One of the characters that distinguish the high school from the earlier grades is the fact that for scientific subjects a laboratory is provided, and no high school is considered as being in any degree satisfactorily equipped without it. But it is to be feared that the laboratory equipment is not so successfully used as it should be, and that it fails to accomplish more than a small proportion of what it is capable of doing. This failure is largely in consequence of the fact that teachers do not make a satisfactory analysis of what the laboratory is intended to accomplish, and the psychological processes employed in its accomplishment. A laboratory in itself is not worth anything. It is only the product that cannot be obtained without it that gives the laboratory value. We need to know what the primary purpose of a laboratory is and what psychological processes are involved in learning that make a laboratory necessary. We need also to know what is the relation of a laboratory method to other methods, and whether two methods are accelerative or inhibitory.

The fact that a laboratory is used does not in itself insure good teaching, and without the good teaching, motivated by a clear understanding of the psychological principles that underlie laboratory work, it may be the poorest method of all.

Primarily, a laboratory is a place in which difficulties may be isolated and attacked one at a time. It is a place in which phenomena can be controlled, and by the variation of a single factor, the effect of each can be described. This isolation of a difficulty is what is known in logic as the process of abstraction, and is one essential requisite for all successful study and for all good teaching. It is impossible to discover how far a body will fall freely in one second, unless there are means for describing the beginning and the end of one second accurately, and designating the time at which the body shall begin to fall and when it shall stop. Primarily then, the laboratory is devised for the purpose of isolating difficulties.

All progress in science, as in other subjects, depends upon the perception of smaller and smaller differences. The process of perceiving differences is called the process of discrimination, and it is an essential factor in all improvement in discovery and in thinking. The laboratory is a place in which is rendered apparent fine distinctions that could not otherwise be discovered.

All good teaching has for its conscious purpose the training of pupils to think. Much of laboratory teaching is poor teaching, and most of this poor quality in teaching is due to an inadequate knowledge of what constitutes good thinking and the conditions under which good thinking is done. For this, psychology has itself been partly to blame in not stating a description of thinking in understandable terms.

Thinking consists in the perception of relations. All of our knowledge may be reduced to two forms, a knowledge of facts and a knowledge of relations between facts. The knowledge of facts, some facts, we may obtain by direct perception; the knowledge of relations between facts is obtained by thinking.

Relations may exist between ideas or between things, and may be of many different kinds. It is possible, however, to reduce all relations to two forms, that of resemblance or difference, and the word resemblance may be employed in a sense that is wide enough to include difference also. When our students begin to discriminate and compare, when they ask themselves how this thing is like or how it differs from some other thing that they know or that they are examining, then they are

thinking and are getting value received for the mental work expended in study.

It is in this respect that much of science teaching is frail and weak. Laboratory work as at present conducted, fails to make it necessary that students shall discriminate, compare and generalize. The acquisition of facts, rather than the perception of relations, is the ostensible and conscious purpose of too much of our laboratory work.

When I have thus described the above limitation on science work, I have not intended to minimize the importance of the acquisition of facts. The acquisition of facts is not a thing to be slighted nor lightly regarded. Before we can do any thinking, we must have at hand the facts between which relations exist. But it is intended to insert the caution, not to omit or overlook the importance of discovering the relations between the facts in the enthusiasm for the discovery of the facts themselves.

The two kinds of acquisitions are not incompatible, but one cannot replace the other. Buckingham has shown that in history there is a positive correlation between remembering and thinking, or between the ability to accumulate facts and the ability to perceive relations. A pupil who surpasses another one point in the ability to remember, or accumulate facts, surpasses that other .89 of a point in thinking.

Laboratory work has a better opportunity than any other kind of a subject to bring out this kind of thinking in a pupil. The perception of relations between ideas is possible only when the ideas are clear and vivid. If the ideas are obscure and weak, the relations do not make themselves apparent.

Laboratory work gives ideas that are more vivid and clear, if the work is well taught, than can be obtained by the study of a textbook or by lectures. The reason for this is apparent, if we realize that the several sensations that enter into a percept, or its reproduction as an idea, are the concomitants of strong, peripherally initiated impulses; while the sensations that constitute the ideas derived from the study of books, or from lectures heard, are accompanied by only weaker, centrally initiated impulses. This is one way of accounting for the difference in the clearness and vividness of the percepts we get from laboratory work, as contrasted with those we obtain from book study.

If the ideas are clear and vivid, the relations between them are more readily discovered, and thinking is more easily accomplished. It is true, that these vivid perceptions and ideas are

better remembered, but it is not the more certain remembering, as some believe, that constitutes the principal merit of ideas obtained from laboratory work.

These three principles, the isolation of difficulties, embodying the psychological principle of abstraction, the finer discriminations, and the developing of clear ideas that facilitate thinking, constitute the basis for all values discoverable in laboratory work. An examination of a bibliography of fifty titles upon the teaching of science discloses the fact that the discussions have principally centered around such questions as the materials that shall constitute the content of any particular science to be taught in the laboratory, the development of the problem method of teaching science and the discovery of appropriate problems, the development of the project method and the invention of projects, and the proper proportion of time to be given to laboratory work and textbook study. These are the topics that constitute the subject matter of nearly all the articles and books published upon the subject in the past fifteen years. None of the discussions properly evaluate the psychological principles involved in the teaching of the subject, and as a result they fall far short of improving the teaching as much as they should. Let us consider these topics in the light of the principles enunciated above.

The problem method consists in the selection of a problem of some kind, and the discovery of some method of solving it. It grows out of a theory of thinking that cannot be stated in the terms used above. The theory of thinking underlying it is that every process of thinking begins by the recognition of some problem or difficulty, a kind of mental circling around it, then the discovery of some method by which the solution can be obtained. A very clear epitome of this theory of thought may be quoted from an article by D. K. Lott, in School and Society, (volume 4): "The origin of reflective thinking is some doubt or uncertainty, a perplexity which makes our belief uncertain. There is in the mind a felt difficulty or problem which demands solution. This results in an act of search for and investigation of facts to satisfy the uncertain state of mind. During this search, the problem becomes more sharply defined, and a probable answer is suggested in the form of a hypothesis which really is only a temporary solution of the difficulty. Up to this point we have an inductive process. But perhaps the answer is wrong, so a process of deduction follows which develops the consequences of the hypothesis,

This leads to further observation and experiment, culminating in a final conclusion of belief or disbelief. Thus a complete act of reflective thinking involves both deduction and induction. It begins and ends with facts, not with generalizations." Mr. Lott insists also that such an act of reflective thinking always involves "the element of emotion."

This statement of the process of thinking would best be described by calling it an example of brilliant artificiality. We shall have to ask what is the evidence that this is a true statement of the actual process of thought. Thorndike is perfectly justified when he says concerning this description of the thinking process: "The notion of thinking as coming to a lack, filling it, meeting an obstacle, dodging it, being held up by a difficulty, overcoming it, is so one sided as to verge upon fantasy." (Psychology of Arithmetic. p. 279.) Thorndike might have used even a stronger expression and called it fantastic. Yet it is this theory of thinking that seems to underly what is described as the problem method of dealing with scientific subjects in the laboratory.

The second topic around which may be grouped the recent discussions of laboratory work, is the so-called project method. Although the project method was thoroughly exploited by Colonel Parker thirty years ago, it has received a pronounced impetus within the last few years. I distinctly remember the playhouse on the campus that had been undertaken as a project by the children in Colonel Parker's School. The project method as properly applied to appropriate subjects has some very distinct advantages. But when it is applied to laboratory teaching, it is either a misnomer or it is very defective. The project method is almost necessary in such subjects as agriculture or school gardening. It has the very great advantage of teaching the different parts of a subject in their proper relation to each other, but it has the decided disadvantage of failing generally to isolate the difficulties, or to demand the finer discriminations, which are the special excellences of laboratory work.

Nearly all persons who discuss the question, make a definite recommendation about the proper division of the time to be given to laboratory and textbook work. It is a common recommendation that two days a week be given to laboratory and three days to textbook recitation. The basis of this division is not very clear. In fact, the psychological principles involved in laboratory work do not justify the division, and an attempt to estimate the value of laboratory work on the basis of this division seems to

show that laboratory work is nullified by the textbook accompaniment. In volume 3 of School and Society, Mr. H. L. Wieman asserts that in his classes, those students who have had laboratory work in their preparatory course take hold of the laboratory work rather more readily than do the others, but in theoretical work and in quizzes they are rather poorer than those who have not had the subject.

This corroborates definitely an experience of my own, concerning which I once made a note in School Science and Mathematics. It was once my custom in teaching physics in a normal school to divide the students into two classes, those who had had physics in the high school in one class, and those who had had no physics in the other. In three separate years, in a carefully conducted experiment leading to the formulation of the laws of uniformly accelerated motion and the measurement of g, where each pupil derived his own data and the results were computed from the average of the entire class, I found that in all three of the years, the class that had not previously studied physics obtained more nearly accurate data and computed a result more nearly in accordance with the facts than did the class that had studied physics in the high school. Those who had studied physics in the high school had used a textbook, and the laboratory work had been rather incidental. The two methods seem to be incompatible, and will not very satisafctorily mix.

Even in chemistry, no dependence can be put on the results reported in weighing, if the pupil or class have already learned from a book what the result of their weighing should be. The influence of expectation will make the balance turn at a certain amount, although the pupil may be unconscious of being influenced in his reading by it.

In my zoology classes, I used for several terms a laboratory manual that gave directions for examining a perch. It happened that it was more convenient for me to secure for examination a sunfish, a very similar fish. The manual of directions told the class where to look for the palatine bones and suggested the presence of teeth by directing them to look for teeth. Nearly everyone in the class would find teeth, although in the sunfish there are no teeth. Similarly, in a normal school class to which I once belonged, we could nearly always count 18 gills in each bronchial chamber of the crawfish Cambarus, which from the statement in the book we believed to be an Astacus, although no Cambarus has more than 17 gills.

Such blunders in observation and statement of generalizations are sure to occur where students are taught to combine book study with laboratory work. Independence and accuracy of judgment can be secured only if the pupil is thrown upon his own resources of observation by laboratory work.

Very few of the approved recommendations in the teaching of science have been put to the test of actual measurement of the product. The recommendation is commonly made that double periods be allowed for laboratory work, and the reason stated is that about three times as much can be accomplished in two periods consecutively as can be accomplished in one single hour. That is the estimate that I made once in organizing a program, and I believed it to be true. After four years experience with such a program, I began seriously to doubt the conclusion. In fact, no one knows just what the relation is between the amount accomplished in single periods and in double periods, for the results have never yet been measured by the processes that are now available. Such experiments and measurements in all phases of laboratory and science work are badly needed.

ARITHMETIC IN THE HIGH SCHOOL.[1]

By L. Gilbert Dake,

Soldan High School, St. Louis, Mo.

The object of this paper is to call attention to some tendencies in the American high school which the writer considers dangerous to the coming generations of high school graduates. It is a plea for a more extended study of practical mathematics. In presenting his view the writer may seem critical and, at times, harsh and radical. He believes, however, that the times are harsh, and require more or less radical statements to cause a change in the present drift of the high school curriculum.

Up to a comparatively few years ago, the object of all public education seemed to be to get students to read well and understandingly, to write legibly, and to figure accurately. Higher education, so-called was left to the colleges and universities. Such a small percentage of the high school graduates could ever attend college that a demand was created for higher education in the local school. Hence the high school was developed. The early high school became a stepping stone to college, in other words a preparatory school for further study in the greater

[1]Read before the Mathematics Section of the C. A. S. and M. T. at Soldan High School, St. Louis, Mo., November 25, 1921.

schools. The course presented was, naturally, that which would make it possible for a graduate to enter most any college without further preparation. It was not considered the function of the high school to fit its graduates for anything in particular; they were supposed to either enter college or go into the industries starting at the bottom along with the uneducated and working up. Many people believed that the high school should do more for the boy who could not attend college; that he could be given a more definite training in the public schools and be thereby fitted to start a little higher up on the industrial ladder of success. As a result, the high school added a large number of courses which we choose to call vocational, the aim of each one being to fit the student for some definite line of work. The high school had then two aims for its entering students, they must either prepare for college, or for a definite vocation.

These two aims, both worthy of any good American high school because of the multiplicity of the subjects necessarily taught, have caused endless conflict. It seems that in the struggle to meet the demands for college preparation, and at the same time to give the student something definite in case he decides not to go to college, many educators have lost sight of some of the most fundamental things necessary for ultimate success.

Mr. William McChesney Martin, Chairman of the Board of the St. Louis Federal Reserve Bank, in answer to a question as to what was the most desired characteristic of a young man entering the business world today said, promptly and decisively, "Initiative." The ability to analyze independently a problem with accuracy, even though it be an entirely new one, the ability to think clearly and logically, the stick-to-it-iveness that carries a person through a difficult solution of a business problem; all these are absolutely necessary to the successful man or woman of today.

Are these qualities born in a person, or can they be acquired by training and education? May the writer ask if a great athlete was just born that way, if a great musician was just the freak of birth, if any really pronounced success was just the result of chance? You who hear this paper will all agree that to every one who has become a pronounced success because of being born a genius there are a hundred who acquired only a limited ability by birth, but who, because of their training became the leaders of today. As teachers of science and mathematics, we are convinced that in the proper amount of the right kind of training lies the

hope of the coming generations. Initiative can be acquired through training the same as we improve or acquire any of the God-given gifts of nature.

We often confuse initiative with impulse. The writer has often heard it said of a person who was very impulsive that they had so much initiative. We more or less admire an impulsive person, but most impulsive people get in the way at times and are more of a detriment than otherwise. Impulse is the wrong brand of initiative. It is the natural born initiative untrained. Initiative of the right sort must come from the person who is able to think accurately, to reason down into the very heart of things, and then to act.

If initiative is a process of correct reasoning, then our schools should have courses designed to develop this faculty. To be able to reason, a person must be possessed of the necessary facts and be able to arrange these facts in a logical way to arrive at a just conclusion. Possibly the best place to teach reasoning is in the science laboratory or in the mathematics classes. These branches deal with concrete facts. The youth of our land must be shown concrete things, not necessarily because his head is part concrete, but because this is an age of doubt and investigation. An instructor of a century ago was believed because his students thought he knew all there was to be known of the subject. So little was generally known of the subject taught, that the student had small opportunity for proof. Nowadays the student accepts no statements of his instructor unless it can be proven by concrete facts. We must recognize this in the student of today and we must satisfy his mind if we are to teach him to reason at all. Because of the exact nature of the reasoning and the concrete materials shown, it seems that the best results should be obtianed from the courses mentioned, science and mathematics.

But, and here commences the sad part of this story, the press of so many different courses, the overcrowding of the curriculum has made it impossible for all students graduating from high school to take a sufficient number of courses in either science or mathematics. The writer is particularly interested in the product of the high school from the commercial field and has made an intensive study of the problems of that course. In many high schools, a student may graduate from the Commercial Course and in fact from many other special courses with practically no training in mathematics. Those who are interested in these courses have demanded so many special types of training,

that the fundamental courses have been crowded out. The academic teachers, on the other hand have done little to stem the tide. They have failed to add things in their courses that would make them more desirable from the standpoint of the vocational student. As a result, both the special course and the college course students have lost much. This fact is proven beyond a doubt, where a so-called general course is offered; the majority of the students will graduate from the general course because it offers them possible college entrance requirements as well as some of the more practical subjects.

The writer can see no reason why the academic courses cannot be practical and at the same time be the best preparation for college or industry. The fault must lie in the subject matter or in the method of presentation.

In the early development of the Commercial Course, it was found necessary to teach a special course in arithmetic. The work in mathematics in the grade schools could not go far enough to train the boy to handle many of the complex problems of the business world. In many high schools, this course in arithmetic was all the study in mathematics offered the graduate from the Commercial Course. This was radically wrong. The study of arithmetic was necessarily a series of mental gymnastics to give the student the power to carry on the fundamental processes of calculation with accuracy and dispatch. It was a means to give the student immediate ability in figures. It did not teach the ability to reason to any great extent though this was all of this type of training the commercial student received.

On the other hand it was not thought necessary that a commercial student needed a course in algebra. In fact it is difficult for the commercial student to take courses in algebra, because of the complexity of the requirements of his course. Yet higher forms of accounting demand a very extended use of the higher branches of mathematics. The difficulty in the past has been that the course in algebra did not attract the commercial student. The regular mathematics teacher will probably feel offended when the writer claims that much of the work now done in algebra fails to produce the desired results. The real teacher of algebra seeks to lead his students into the realm of mathematical reason; he strives to prepare them to reason out the problems of life through the unknown quantity in the algebraic equation. He seeks to reduce everything to equations, and thereby, lay the foundation for more intensive study of mathematical problems.

Unless he is an exceptional teacher he fails in the one most vital aim of teaching, that of getting his students to realize the connection between algebra and his possible life work. The student takes the course in algebra because he has been advised that it is a necessary foundation for his career. In most cases he is however, unable to trace any connection, either before or after, with his life work. The study of algebra has gone into so much disrepute that it is no longer required for graduation from many high schools.

The relegating of algebra to the background is one of the most serious and dangerous tendencies of the high school today. It must be given its place of prominence once more. As teachers, we all realize what the study of mathematics means in the development of the future man, but it is hard to show parents when they are convinced that their boy can get along just as well without it. People to-day are looking for immediate results, they want something *now*. Unless a course in high school shows some real practical value *now*, the parent is against it, or at least indifferent. No matter how strongly we may feel that the substitution of anything for a strong course in mathematics is radically wrong, the fact still remains that outside interests are demanding the substitution of other subjects for algebra.

A proper solution of this situation seems to demand the offering of a course in general mathematics covering a period of four terms work. The algebra teachers are constantly faced with the problem of students who are weak in the fundamental principles of mathematics, they cannot add, subtract, divide, or multiply. The present algebra teacher would be much better off if the student were given a strong course in these fundamental principles before touching algebra.

On the other hand, a boy enters high school and finds himself in a different atmosphere, he is treated differently, is left to get his work by himself to a considerable extent. There is a great gap between the grade school and the high school in the method of instruction. Often the new student is so bewildered that he is a long time finding himself. The large number of those taking algebra who fail the first term is a good illustration of the point that we need some more mathematical instruction before delving into algebra.

The number of students who leave high school is the greatest in the first year. What becomes of these students? They do not go to college, they go to work. Then we ought to give in the

first year in high school those courses that make it possible for the large number who will be forced to leave school to get something definite and practical. Algebra will do them no particular good but arithmetic will. The kind of arithmetic given should not be the same given in the grades, but it should be of such a character that it will take the same value as preparation to college as any other branch of mathematics.

What should we teach in this course in arithmetic? Most teachers just follow the book right through, "Tomorrow we will take the next ten problems" is the assignment of the average teacher. The writer has never seen arithmetic taught to suit him, but he believes it can be taught so that the student will see its intense practical application and also realize something of the romance of the workaday business world. A great deal has been written already about teaching mathematics objectively. If there is any subject that should be taught that way, it is high school arithmetic.

In the first place, the arithmetic course should be divided into a number of units, varying in their subject matter in accordance with the needs of the community. If I were teaching in a distinctively farming community I would use those units having direct bearing upon farming and farm products. I would teach units laying emphasis upon weights and measures, a distinct unit teaching the mathematics of marketing, one treating of the problem of transportation, one on money and banking. Of course along with these units would be a continuous drill on the fundamental principals of calculation. Any boy taking this term's work would be fitted to handle the necessary calculation in the farming community.

For the metropolitan district, these units should be varied—bring in a study of factory payroll, the sale and purchase of merchandise from both the retail and the wholesale standpoint, billing, and a great many others. These units would of course be placed in the course in such a logical way that if the pupil dropped out at any time he would have something definite to depend upon for a job. In the great majority of cases, the students who drop out of the school in the first year or two in the large cities either become clerical workers or factory hands. This training in arithmetic would help them get a better job.

The student who wished to go on and finish his course would find algebra much easier after the course in arithmetic, and he

would be less liable to drop school because of failure in mathematics. A bridge would thus have been thrown across the gap separating the grade school from the high school; no, the millenium would not have been reached, but the boy going out of our high school either a graduate or a "quituate" would be vastly better fitted to cope with the problems of life.

The study of arithmetic in high school should not be limited to the commercial student, but it should be a part of the fundamental study in mathematics so necessary to training the mind of the American boy.

SCIENCE OR ATHLETICS?[1]

ABSTRACT

By E. G. Mahin,

Professor of Analytical Chemistry, Purdue University.

External crticism of scientific education in the colleges largely takes the form of discussion of the content of courses and of the methods of administering them, from the standpoint of immediate applicability to practical industrial performance. College teachers welcome such discussion and they are anxious to improve the quality of their work wherever possible, in conformity with all constructive suggestions. But it is believed that another aspect of the question needs emphasis and that it is possible for assistance to be rendered by those who are not convinced that the colleges are working with sufficient effectiveness.

The steady increase in extra-curricular activities in our colleges is believed to be largely responsible for the much discussed decline in our standards of scientific education. It is believed also that the abnormal development of commercialized intercollegiate athletics is the greatest obstacle to our effort to restrict such activities to sane and reasonable limits. Our standards cannot be materially improved until the colleges divorce themselves from commercialized athletics and this necessarily involves elimination of the high salaried professional coach and correction of the existing disproportion in expenditures for athletics and for educational purposes. This is largely a responsibility for those outside the college, since the principal supporting influences for the present athletic system have been found in organized college alumni and business men.

The athletic program now proposed for a number of educational institutions cannot be justified upon the basis of any real

[1]Read at the Birmingham meeting of the American Chemical Society, April 2, 1922.

benefit to be derived by the mass of students from the present athletic system. The building of athletic stadia costing millions, while acute educational needs remain unsatisfied, is little less than a betrayal of the cause of education to commercialism. Neither scientific training nor scientific research can reach its highest development while our entire program for physical education concerns itself with an almost negligible minority of men and leaves the vast majority of students upon the bleachers.

GRAPHICAL TRISECTION OF AN ANGLE.[1]

By E. D. Pickering,

Cleveland, Ohio.

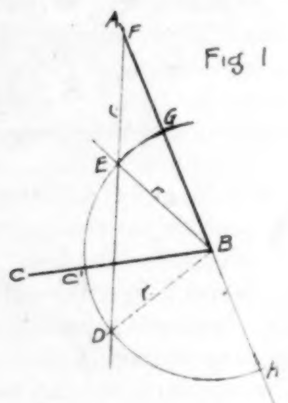
Given: $\angle$ABC.

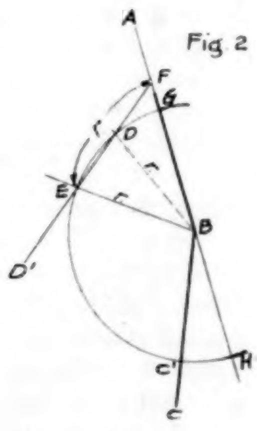
Required: Trisect graphically.

Construction.

Produce one side as AB.

Describe an arc using any radius with B as center, cutting AB produced at G and H, and BC at C′.





Make DH = GC′. Draw DB.

Mark off on straight edge a distance equal to radius DB.

Maintaining straight edge on D move remote mark along GA

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[1]Note by the Math. Ed.: A different method of trisecting an angle by means of a graduated ruler and compasses was published in this journal in 1913. Like the method given above it was, of course, not Euclidean. From the time of Hippias of Elio (about 420 B. C.), who invented the curve called the quadratrix by means of which an angle can be trisected, a solution of the trisection problem has been attempted by mathematicians and non-mathematicians alike. The first rigorous proof of the impossibility of the trisection of any given angle by means of an unmarked ruler and compasses is credited to Pierre Laurent Wantzel (1814-1848).

until other mark cuts arc. Designate these points, respectively, F and E, thus making EF = DB. Draw BE.

Then $\angle$EBF = $\frac{1}{3}$ABC.

PROOF.

In Fig. 1:

$\angle EFB = \angle EBF = \frac{1}{2}\angle BED = \frac{1}{2}\angle BDE$,

or $\angle BDE = 2\angle EFB$.

$\angle EFB + \angle BDE = \angle DBH$.

Substituting $2\angle EFB$ for $\angle BDE$,

$\angle EFB + 2\angle EFB = 3\angle EFB = \angle DBH$.

$\therefore \angle EFB = \frac{1}{3}\angle DBH$.

But $\angle DBH = \angle ABC$ by construction and $\angle EFB = \angle EBF$,

$\therefore$ by substitution $\angle EBF = \frac{1}{3}\angle ABC$.

In Fig. 2:

When D lies between E and F substitute BED′ for BED and BDF for BDE and proceed with $\angle EFB = \angle EBF = \frac{1}{2}\angle BED' = \frac{1}{2}\angle BDF$ etc.

For angles greater than 180° bisect and proceed with either half, so that the remaining two thirds of the half angle is adjacent to the side of the angle.

THE NEW ENTRANCE REQUIREMENT IN CHEMISTRY AT MASSACHUSETTS INSTITUTE OF TECHNOLOGY.[1]

By Arthur A. Blanchard.

The purpose of the entrance requirement is not to make more advanced work in the college course possible; it is to establish a coordination of the high school and institute courses so that the latter may follow the former without discontinuity and without the sort of repetition that is demoralizing. It is of the spirit in which we hope that this coordination may be accomplished that I wish to speak.

Up to the present it has been an unsolvable problem at the institute how to give any adequate recognition to the excellent training some of our students have had at high school and still treat fairly those students who have had no previous chemistry. That the instruction in the high schools is good is evidenced by the one or two young men who almost every September take and pass with a very high rating our entrance examination for advanced standing in chemistry. Perhaps they have had more than one year of high school chemistry. These men are admitted at

[1]Read at meeting of New England Association of Chemistry Teachers, Boston, February 11, 1922.

once to our second year courses in chemistry and there do credit to their earlier training. But it is only the very exceptioanl young man who has thus drawn the full amount of benefit from his high school training. The average good student would be hopelessly lost were he to try to enter such an advanced course. It is to the average good student that this discussion is devoted.

But the average good student feels aggrieved and loses interest if he is mixed with others with no previous chemistry, and has to repeat the drill in simple conceptions which he feels he already understands.

Although a student may have forgotten his chemistry during the summer so that he could never pass an examination, nevertheless it is astonishing how the background of chemistry he has acquired helps him to comprehend what we have to offer him. Science demands a continued repetition of basic principles applying them ever to new knowledge and to more complicated cases. Although the student may balk at repetition of the principle in the same old setting, he becomes interested when he sees that principle being put into difficult and embarrassing situations and changing confusion into understanding. It makes him want to get a better acquaintance with the principle and willing even to go back and review if need be the principle in its simplest aspects.

The institute hesitated for long before putting an added burden on the high schools. A year ago last spring Professor Phelan sent a circular letter to the schools requesting opinions upon the subject and the replies showed a practically unanimous agreement that such an entrance requirement as he proposed would entail no hardship on the schools. For such candidates as come to us without having fulfilled the entrance requirement, the Institute now offers an entrance course beginning in the latter part of August and lasting five weeks.

We think that our entrance requirement in chemistry is unique in that no examination is required, simply a certificate that the student has taken a course of at least 150 hours and has shown diligence and reasonable intelligence.

We have no desire for the schools to establish special courses in college entrance chemistry and cram the pupils to pass an examination upon topics in a college entrance syllabus. In fact, we feel in many ways it is an advantage for the pupil to study chemistry in the class that ends its schooling with the high school.

School boards and parents are prone to demand practical usefulness from science courses. Teach the child something that will enable him to earn money or to save money, or to avoid sickness. The teacher knows the limitations to the usefulness of mere practical information, uncorrelated by general principles, but the teacher doesn't tell the school committee or the parent that it can't be done; he cheerfully tells them he will teach the chemistry of bread making, or of combustion, or of physiology, or of coloring, or of metals, or building materials, or what not, and he goes ahead and teaches fundamental principles, emphasizing every point of contact with practical daily life. Thus we at the institute are sure to be satisfied if the pupil has the background of 150 hours training with a capable teacher whatever special emphasis may have been given the course.

I have anticipated I might be asked what particular topics in chemistry we should assume the pupil to know before starting with us and the list I shall give will not be long. It is as follows:

Pure Substance and how to recognize it.
Element.
Compound.
Law of definite proportions.
Atomic weights.
Familiarity with the more characteristic properties of oxygen, hydrogen, chlorine, nitrogen, argon, sulphur, sodium, calcium, magnesium, copper, aluminum, iron, lead, silver, gold.
The essential difference between a metal and a non-metal.
Acids, bases, neutralization.
The law of combining volumes of gases.
Symbols and formulas.
Chemical equations and their interpretation.
Exothermic reactions: combustion and liberation of energy.

Such a list of topics has about as much meaning as a bill of fare. An extensive and flowery bill of fare at a cheap eating house does not mean much. But a plain bill of fare at a hotel of high reputation means satisfaction.

This bill of fare is couched in simple English and the seasonings and garnishings are not even mentioned, much less enumerated with French names. Knowing the reputation of the schools and teachers who are to serve it we are confident that the meal will be good, that the substantial courses will be seasoned and palatable; and that parsley, pickles, olives, celery, bonbons, nuts, whatever garnishings are suitable, will appear at the proper places to make the meal attractive as well as nutritious.

We trust to the skill and discretion of the cook in preparing a meal; we might even with safety leave the bill of fare to the competent cook. Likewise we leave the course in chemistry to the

competent teacher, knowing that although the topics mentioned suggest and involve other topics, not mentioned, and in fact if pursued exhaustively would embrace the entire realm of science, the teacher will treat these topics with discretion and make each one of them present some clear and tangible, yet simple, conception to the student's mind.

Finally, I might state again the things we do not want, and the things we do expect to gain from this entrance requirement. We do not want a prescribed course in high school which will take up certain things and abstain from all others and will stop at a definite point, from which point we are to start with machine-like precision. Such an accomplishment would be impossible to bring about anyway, but, were it possible, we would not want it.

What we do expect is to gain for our students a background of experience—some acquaintance with common elements, their compounds and their reactions, and some appreciation of general principles through which chemical knowledge is correlated, but most of all an interest in chemistry and an eagerness for more knowledge and more understanding of this subject. We feel very confident that the high school teacher cannot help giving this desired background, whatever practical aspects of chemistry may have been accentuated in the course.

I was careful to emphasize that the list of topics, in one sense, meant nothing at all. It means no limitation upon the choice of the teacher because no topic is included which any teacher would even consider omitting from a 150-hour course. It is to be expected and hoped that the high school course will go outside this list. No industrial or practical topics are included because it is taken for granted that they will be used in varied ways to enrich any course. Neither are Avogadro's hypothesis, nor ionization included, but very few teachers will refrain from introducing them. These two topics are typical of a certain kind which must be taught thoroughly in college. I think that this will entail no burdensome repetition of what may have been taught in high school. Certainly these are topics which are capable of ever expanding applications even to the most advanced departments of chemistry.

And yet we are very confident that the background represented by the topics of our brief list will give what we need on which to build a college course which will hold the enthusiasm of the best students while it does not run beyond the comprehension of the average ones.

A CLASSIFICATION OF THE BOTANICAL SCIENCES.

Oran Raber,

University of Wisconsin, Madison.

Within the past twenty years the sciences have expanded so rapidly that the phases of a particular science which in 1900 were small chapters of the whole, are now in some instances grown so large as to require independent treatment and have become complete entities in themselves with subdivisions of their own. Because of this expansion it becomes necessary from time to time to stop and take account of our stock of knowledge, to see just what are the precise limits and the scope of the subdivisions of our subject, and to define as clearly as possible the various branches which make up the parent tree.

We realize that all classifications are, for the most part, purely arbitrary creations but creations nevertheless which have a distinct pedagogical value and a place in our scheme of thought. It is with this in mind that the following classification of the botanical sciences is proposed.

First, what is botany? The word botany comes from the Greek *botanikos*, meaning plant, and the science of botany is the science which treats of plants. Unfortunately, the word, botany, is often associated in the public mind with courses in female seminaries and a botanist is frequently conceived as a long-haired visionary roaming the fields in search of some rare specimen. For this reason it is a pity that the word *phytology* (from Greek *phyton* = plant+*logos* = discourse) has not come into more general use, thus putting the name on an equal footing with zoology, geology, psychology, etc.

Having thus defined the general scope of the subject, we can then divide our field very easily into the *pure* sciences and the *applied* sciences. What is pure botany and applied botany and how can they be differentiated? Pure botany is the study of plants with no regard to their relations to man but from the point of view of the plant alone. That is, in pure botany all practical considerations, all benefits to man, are out of the question; it is merely study for the sake of the study. Applied or economic botany, on the other hand, is the study of plants with a view to applying the knowledge gained to human needs. Pure botany is taught primarily in our colleges of arts and science while applied botany is taught primarily in the colleges of agriculture, medicine etc., as we shall see later. No one would be so bold as to say that these lines are drawn sharply in practice or even that they

should be, but in theory these are the limits and it is well for us to know what they are.

Pure botany is also an ill-chosen term because it seems to imply that there is something more ennobling, more scientific, and more honorable about the pure sciences than the applied sciences. Fortunately, the number of scientists who consider a thing bad because it is useful is rapidly diminishing, and it is certainly not the intention of the writer to discredit the applied sciences in any way.

To the subject of pure botany there are two great divisions. First, there are the subjects which deal primarily with structure or composition, and secondly, those which deal with function or operation—the one group chiefly concerned with plant *statics*, the other with plant *dynamics*.

The structural subjects in turn fall into two categories. First, one may consider the group of subjects which is concerned with structures *per se*, and secondly, the group which is concerned with structures because of the light these studies throw upon the problems of evolution. The first group make up what is known as *morphology* (Greek *morphos* = form+*logos*) while in the second category we have the branches of *systematic* botany (Greek *systema* = whole) whose business it is to build the family tree of the plant kingdom.

Morphology also may be divided into two groups of studies. These are the subjects which consider structures primarily in their relation to *time* and those which consider them primarily in relation to *space*. Embryology (Greek *en* = in+*bryo* = swell) is hence the study of the progressive changes in form and structure during the development of a particular organism. To be sure, space relations must also be considered, but the emphasis is placed upon the time element.

Morphology as considered from the point of view of spatial relations has three main divisions—cytology, histology or minute anatomy, and gross morphology. Cytology (Greek *kytos* = hollow place or cell) is the study of the units of the organism—units which we call cells although we now know that in the living tissue they are not empty places as was thought by the first investigators. Some cytologists may insist that their subject is as much concerned with function as with form and it can not be denied that modern cytology is interesting itself very much in function, but neither can it be denied that the *main* interest of cytology is in form. The functional aspects of their subject have

been taken over by another group of workers—the geneticists—as we shall see later.

Histology (Greek *histos* = web) or minute anatomy (Greek *ana* = up+*temno* = cut) is the study of the tissues and their relations on one hand to the units—the cells—of which they are composed and on the other to the organs which they form.

Gross morphology is that branch of the subject which treats of the relations of the larger units—the organs—to the plant body or organism.

Turning now to systematic botany, we see that it also has two main divisions. First there is the branch of the subject known as taxonomy (Greek *taxis* = arrangement÷*nomos* = law) which concerns the classification of plants now living on the face of the earth, i. e., *extant* plants, and which endeavors to show by a study of the structures of these plants their relations to each other in the evolutionary scale, to determine which forms are the more recent, and the exact degree of relationship existing between the members of the plant kingdom.

Paleobotany (Greek *palaios* = ancient), on the contrary, tries to solve the problems of phylogeny and evolution by studying forms which exist only as fossils, i. e., by studying *extinct* forms as opposed to extant ones.

There are some who insist that nomenclature (Latin *nomenclatura* = list of names) is a science and a division of systematic botany. This view can hardly be accepted. As practiced now, nomenclature is far from being a science. The giving of name could be a fairly simple matter if the students who interested themselves in this subject would take the point of view which is generally associated with the word, scientific. Instead, nomenclaturists at the present time are chiefly engaged in petty squabbles and in extricating themselves from difficulties of their own fabrication.

This serves to delimit the provinces of morphology and systematic botany but there exists a special field connecting them in which the emphasis is placed with equal stress upon form *per se* and form for the sake of determining relationships. This field is known as comparative morphology and is hence a connecting link between systematic botany and morphology. The workers in this field have divided up the territory along the lines of the great divisions of the plant kingdom and call themselves algologists, mycologists, bryologists, etc., depending upon whether their special field is the algae, fungi, mosses, etc., respectively.

Among the subjects which treat of plant functions, there are two main divisions—physiology and ecology. Physiology (Greek *physis* = nature) is perhaps not a well-chosen term but at the present time it has been narrowed to mean the study of function and operation or, in other words, plant behavior; and especially the behavior of plants when grown under experimentally controlled conditions in the laboratory as contrasted with ecology (Greek *oikos* = home) which considers the behavior of plants out-of-doors in their natural environment.

This much is sufficient to define in general terms the great divisions of the so-called "pure" botanical sciences, but just as we have seen that morphology and systematic botany are connected by a series of subjects called comparative morphology where equal stress is laid upon structures *per se* and their evolutionary significance, in like manner there exist special studies connecting physiology with systematic botany and also connecting physiology with morphology where the stress can not be said to be located more on one element than on the other.

Plant Geography which considers the distribution of species in the light of the factors of heat, illumination, moisture, etc., which determine plant growth is thus a connecting link between the two great divisions of ecology and systematic botany; while, in a similar manner, the science of Experimental Morphology which attempts to show the relations existing between form and function is obviously a connecting link between the great divisions of physiology and morphology.

Turning now to the the applied phases of botany, let us examine these branches and see what are the chief regions in which man is studying plants not for the sake of knowledge about the plant but in order that he may ameliorate his own condition. Pure botany may be considered as the *impersonal* phase of the subject and applied botany as the *personal* phase.

Plants are studied with a view to improving man's condition in four large fields—agriculture, forestry, medicine, and landscape architecture.

Agriculture (Latin *ager* = field + *cultura* = culture) has broadened its original scope and may now be defined as the science of increasing the world's supply of good food. This requires a consideration of animals as well as plants, but since all food comes directly or indirectly from plants, agriculture is primarily a botanical science. To date there are five branch sciences dealing more or less intimately with plants — agronomy,

bacteriology, genetics, horticulture, and plant pathology.

Agronomy (Greek *agros* = field+*nemo* = distribute) has now come to mean the study of soils and their relations to the plants grown upon them. Hence the agronomist considers not only the food elements in the soil—its chemical condition—but also its porosity, water holding capacity, specific heat, etc.—its physical condition—all these studies being made with a view to the plant life which the soil is able to support

Bacteriology (Greek *bakterion* = rod) is the science which deals with the group of organisms known as bacteria. Agricultural bacteriology is chiefly interested in the bacteria of the soil and more especially with those forms associated with leguminous crops as well as with those which are related to the processes of nitrification and denitrification, ammonification, etc.

Genetics (Greek *genesis* = origin) is the science which deals with the originating of new varieties and species of plants and has come to mean almost exclusively the forming of new types by intercrossing or by plant breeding. Obviously, there is the science of animal genetics as well, and it is also evident that genetical studies may be carried on from the point of view of pure science. Hence there are many geneticists who are in the field of pure botany but, since the subject is of such a nature that the applied phases can teach as much from the "pure" point of view as any other and in addition have a practical value, the applied botanists are rapidly taking over this field. It should, however, be noted that the "pure" geneticist is interested chiefly in the changes in the cell constituents of the plants experimented upon and is hence a cytologist, while the practical geneticist is interested in obtaining a useful plant. Since, as has been stated, genetical studies are chiefly studies in reproduction which is a phase of physiology, genetics may also be considered as a phase of physiology and was in fact so considered until it declared its independence as a separate subject. It is the newest of the botanical sciences and is hence the most difficult to place with precision simply because its scope has not yet become clearly delimited. However, since the majority of the botanists who are in this field at the present time are plant breeders and are interested in the economic aspects of the problem, we must consider plant genetics as a branch of agriculture.

Horticulture (Latin *hortus* = garden) is the science devoted to the growth of garden and orchard crops.

Plant pathology (Greek *pathos* = suffering) is the science

which treats of the diseases of plants. Most of these diseases are produced by parasitic plants, and in the past pathology has largely restricted itself to a study of these destructive parasites. There is, however, a growing tendency among pathologists to realize that their field should also include physiological maladies as well and that any kind of malfunctioning whether produced by another organism or whether produced by physiological states within the plant is equally comprised within the scope of their subject.

Forestry (Latin *foras* = out-of-doors) is the science which deals with the production, conservation, and use of the world's supply of wood. Since wood is produced only by plants, forestry is a botanical science. It has two main divisions—sylviculture and wood technology.

Sylviculture (Latin *sylva* = forest) is the science of the production and conservation of forests and in the popular mind is frequently considered as a synonym for forestry.

Wood technology (Greek *technikos* = art) is the science of the use of wood. The wood technologist tries to find what woods are best adapted for certain purposes, to find methods of preserving wood, and in brief to make the existing supply of wood of the greatest use to man.

Medicine (Latin *medicinus* = physician) is the science of keeping the human body in good health and in the best possible condition. Inasmuch as at the present time man's greatest enemies are the pathogenic bacteria and since at least 75 per cent, of the curative medicines administered are derived from plants, it is easy to see that medicine is indirectly, if not directly, a botanical science. Two of its divisions—bacteriology and pharmacology—are directly concerned with botany.

Medicinal bacteriology is the science which treats of pathogenic bacteria while pharmacology (Greek *pharmakon* = drug) is the science of drugs and hence of the plants from which these drugs are derived.

Landscape architecture (Greek *architkton* = master-builder) is the science of improving the surface of the earth to better suit man's esthetic nature. It is hence a connecting link between the botanical sciences and the arts. Two of its branches—floriculture and landscape gardening—are primarily related to plants.

Floriculture (Latin *flos* = flower) is the science of the growth of ornamental plants. Landscape gardening is the science which

treats of the arrangement of flowers, grass, trees, etc., so as best to harmonize with the environment of buildings, walls, and other structures. It is obvious, however, that the landscape architect must know something of soil requirements, season of blossoming, rate of growth, etc., of the plants employed if he is to obtain the most satisfactory results. In other words he should also be a botanist.

Here concludes this brief summary of the botanical sciences as they are at present divided and distributed among the various workers in the field. It is hoped that this classification may be of some value in clarifying the subject and that it may assist those teachers who are searching for a comprehensive classification of phytological studies.

Below is appended in the form of a key for ready reference the sciences described in fuller detail above.

Classification of the Botanical Sciences.

I. Pure botany—science for the sake of science.
  1. Structure dominant idea.
    A. Evolution not main interest—MORPHOLOGY.
      a. Time relations dominant—EMBRYOLOGY.
COMPARATIVE MORPHOLOGY.
      b. Space relations dominant.
        1. The cells—CYTOLOGY.
EXPERIMENTAL MORPHOLOGY.
        2. The tissues—HISTOLOGY or MINUTE ANATOMY.
        3. The organs—GROSS MORPHOLOGY.
    B. Evolution main interest—SYSTEMATIC BOTANY.
PLANT GEOGRAPHY.
      a. Extant plants—TAXONOMY.
      b. Extinct plants—PALEOBOTANY.
  2. Function dominant idea.
    A. Plants under laboratory conditions—PHYSIOLOGY.
    B. Plants under field conditions—ECOLOGY.

II. Applied or economic botany—science for the sake of man.
  1. Production of food—AGRICULTURE.
    A Relation of plant and soil—AGRONOMY.
    B. Soil bacteria—BACTERIOLOGY.
    C. Plant-breeding—GENETICS.

D. Garden and orchard crops—HORTICULTURE.

E. Plant diseases—PLANT PATHOLOGY.

2. Production and conservation of wood—FORESTRY.

A. Forest management—SYLVICULTURE.

B. Use of wood—WOOD TECHNOLOGY.

3. Maintenance of health—MEDICINE.

A. Pathogenic bacteria—BACTERIOLOGY.

B. Medicinal plants and drugs—PHARMACOLOGY.

4. Beautifying the earth's surface—LANDSCAPE ARCHITECTURE.

A. Cultivation of ornamental plants—FLORICULTURE.

B. Harmonious arrangement of plants, etc.—LANDSCAPE GARDENING.

THE PRESENTATION AND IMPORTANCE OF REVERSIBLE CHEMICAL REACTIONS.

By Max Small,

High School, New Haven, Conn.

When I was a senior at high school it was our custom to have a celebration on the afternoon preceding the senior banquet. About one hundred seniors gathered and received instructions from a committee which had mapped out a course of procedure much more carefully and conscientiously than they ever would have done had it been a regular school assignment. I shall now describe part of this program as it was enacted.

To give the affair color the committee secured an equal number of blue and white hats. We arranged ourselves two abreast, a boy with a blue hat beside a boy with a white hat and marched down town until we reached a corner drug store in the center of the city. The store was rectangular in form and had two doors, X and Y, as shown in the first diagram. We marched in and as soon as we reached the middle of the store a signal was given. Its significance was well understood. Those of us who were within the store quickly broke ranks and arranged ourselves in single file, alternating a boy with a blue hat and one with a white hat, while the rest continued two abreast. With almost the winking of an eye we had assumed the configuration shown in the first diagram where B represents a boy with a blue hat and W one with

a white hat. We adopted this arrangement because we knew that the space available would not permit everyone to march singly.

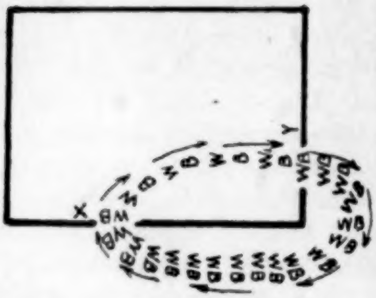


Fig. 1.

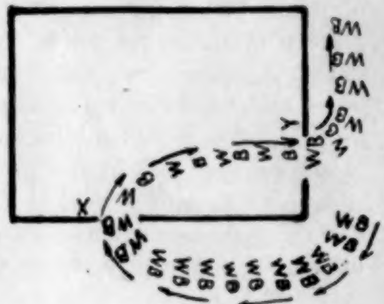


Fig. 2.

We then started our elliptic journey in and out of the store, breaking away from our partners upon entering the store and joining them upon leaving. We continued this itinerary until we became as weary of looking at the clerks as they at us. Then a second signal was given and we all left the store joining our partners and marching away two abreast as shown in the second diagram.

Now, the average person, watching our ridiculous parade in and out of the store, if asked whether we were then in a state of equilibrium would have laughed and replied in a most decided negative. However a reflecting chemist asked the same question would have replied in an equally convincing affirmative because in chemistry the term equilibrium is used in a special sense. From the point of view of chemistry a state of equilibrium may be maintained even if the reacting substances are in a constant state of motion provided the relative quantities of the different substances involved in the reaction do not change. In this case, we were in a constant state of motion and yet as long as we maintained the configuration shown in the first diagram counting at successive intervals one would have found a constant number of "blue-hatted" boys and "white-hatted" boys marching singly and in pairs because as soon as two boys united at one door two others separated at the other.

Chemistry abounds in analogous examples. Let us consider the equilibrium in a copper sulphate solution. The salt is thrown into a beaker. The chemist adds a little water and stirs the mixture. This is the first signal. Some of the copper radicals immediately break away from their partners, the sulphate radicals,

and begin their journey in the solution as copper ions and ulphate ions while others remain unchanged and move about in the solution as molecules of copper sulphate. After a certain amount of this splitting up has gone on, some of the copper ions reunite with their partners to form molecules of copper sulphate but at the same time, somewhere in the solution an equal number of molecules split up into ions. The copper ions, the sulphate ions, and the copper sulphate molecules are in a constant state of motion, ever uniting and separating and yet if counted at successive intervals we would find a constant number of copper ions and sulphate ions and a constant number of copper sulphate molecules. Chemists have adopted the expression *state of equilibrium* to denote this state of affairs and *reversible reaction* to denote a reaction of this type.

In this connection it might be pointed out that if the drug store had been larger more boys would have found it necessary to separate from their partners. In like manner if the chemist had poured a larger quantity of water on the salt more molecules of copper sulphate would have been dissociated. Here, too a state of equilbrium would have been reached eventually but it would have been different from the preceding since the constant denoting the number of copper ions and sulphate ions would have been larger while the constant denoting the number of undissociated copper sulphate molecules would have been smaller. Furthermore, if the store had been still larger all of us might have found it necessary to separate from our partners and march singly. In like manner if the chemist had poured enough water on the salt all the copper sulphate molecules would have dissociated and the action would have gone to completion in the direction indicated by the equation $Cu\,SO_4 \rightarrow Cu^{++} + SO_4^{--}$

Let us now recall the second signal and the second diagram showing the manner in which we left the drug store. The chemist lights his bunsen burner and begins to evaporate the solution. This is his second signal. The ions begin to unite to form molecules and after the water is evaporated all the ions will have joined their partners and the reaction will have gone to completion in the direction indicated by the equation $Cu^{++} + SO_4^{--} \rightarrow Cu\,SO_4$

To make clear to the student that what has been said is not limited to ionic equilibrium other examples of reversible reactions should be taken up at this point. The writer has found these useful:

$H_2O + Co_2 \rightleftarrows H_2CO_3$ (1)
$2SO_2 + O_2 \rightleftarrows 2SO_3$ (2)
$N_2 + 3H_2 \rightleftarrows 2NH_3$ (3)
$N_2 + O_2 \rightleftarrows 2NO$ (4)
$NH_3 + 2O_2 \rightleftarrows HNO_3 + H_2O$ (5)
$ZnCl_2 + H_2S \rightleftarrows ZnS + 2HCl$ (6)

After the student has mastered the idea that equilibrium does not imply the absence of motion but that it implies a motion wherein the relative quantities of the reacting substances remain constant, it should be made clear that the chemists are able to determine how far a reaction has gone in either direction at equilibrium and that in some cases they have been able to impose conditions that disturb the equilibrium in the desired direction. The conditions that effect equilibrium are changes in concentration by adding an excessive amount of one of the reacting substances or by removing one of the products of a reaction, by imposing special pressure conditions, by varying the amount and kind of energy, and by the use of a catalyst.

At this point I would like to take up a discussion of the importance of each of these reversible reactions. Let me indicate the trend of this discussion briefly.

The first one is made to go the right by increasing the concentration of carbon dioxide and by the use of pressure; this is utilized commercially in the manufcture of soda water which we all enjoy. The second is made to go to the right by using the proper temperature conditions and by the use of a catalyst; this is the crucial point in the manufcature of sulphuric acid, generally considered the most important chemical. The third is made to go to the right by the use of proper temperature conditions, a calalyst and the constant removal of the product of the reaction; the fourth by the use of electricity; the fifth by the use of proper temperature conditions: the importance of these three is due not only to their use in the manufacture of explosives for war and peace, but the life of the race in the near future may depend on the economical production of nitrate for fertilizer. The sixth is made to go to the right by removing one of the products of the reaction, the hydrochloric acid: this reaction is typical of several upon which the separation of the elements for qualitative analysis is based.

There are several reasons why I believe in a discussion of this kind. It brings out the industrial value of chemistry. It gives

me a convenient way of emphasizing and cataloging several important chemical processes. It brings out the effect of conditions on chemical action, conditions which are extremely important and which we are so apt to overlook on account of our system of chemical shorthand. It discloses one of the great problems of chemical research, the discovery of conditions that will make a reaction go to completion in the desired direction successfully and economically, problems which we teachers must present in such a manner that they will serve both as a challenge and inspiration to those boys and girls whom we would recruit as the future leaders in our science.

A GENERAL GAS LAW APPARATUS.

By Jacob Jordan,
Oregon Agricultural College, Corvallis.

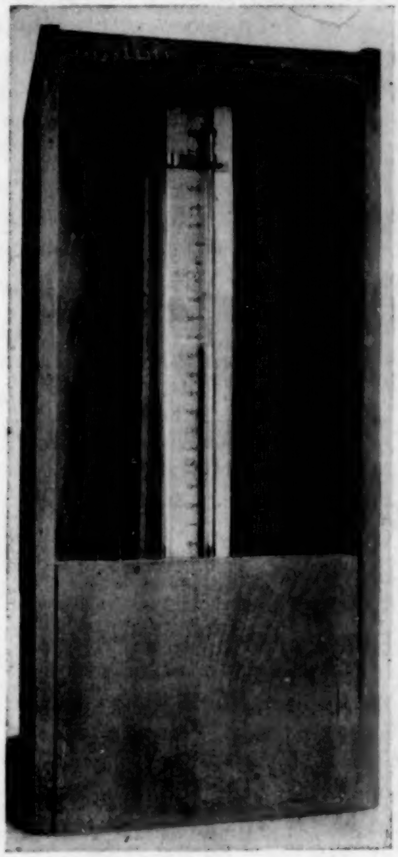
The apparatus which is described in this article is the result of a request from one of the engineering schools of this college, that the Physics Department include an experiment on the general gas law in its laboratory course.

While there is nothing fundamentally new about the apparatus, the writer has never seen it described or used. This description is given because of the satisfactory results obtained in the freshman laboratory.

As a first attempt an ordinary Boyle's Law apparatus was placed under a sheet iron cylinder closed at the top, and a heating coil was placed inside of the cylinder so that the temperature, volume, and pressure of the air in the Boyle's Law tube could be varied simultaneously. Readings of the temperature of the confined air and of the height of mercury in each arm of the tube were taken simultaneously. With the temperature continuously rising, a series of readings were taken and PV/T calculated. The results were so enocuraging that it was decided to modify the apparatus; the accompanying photograph shows it as finally constructed.

A glass U-tube about 12 inches long was sealed flat (not hemispherical) at one end. A piece of a meter stick was placed behind the arms of the U, and the two were fastened to a wider support. The support was then placed in a wooden box, with a glass front, of dimensions 15x6x7.5 inches. A thermometer can be inserted in a hole in the top of the box, preferably with its bulb about half-way between the top and bottom so that it will indicate the average temperature.

Behind the U-tube support, the heating coil is suspended by heavy copper wire leading to binding posts on the rear of the box. The coil is about 8 inches long and 1/4 inch in diameter, and is made of 24-gauge manganin wire.



For a large laboratory section, several of these pieces of apparatus, preferably of different resistances, so that the rates of heating will be different, can conveniently be connected in series with a single rheostat and ammeter, to a 110V AC main. In practice it has been found advisable to start with a current of about 2.5 amperes and to increase this by steps to about 3.5 amperes. Too rapid heating will cause the thermometer to indicate too low a temperature.

Having the tube filled with dry air is of prime importance in obtaining results that really give a constant value of R, com-

puted from PV/T, as can be seen from the accompanying tables of data. Table A refers to a tube containing a high percentage of moisture, B to one containing ordinary room air, and C to one containing dry air. Table C was obtained with a tube that had been heated and evacuated to drive off the occluded gases and filled with air bubbled through concentrated sulphuric acid, the heating, evacuating, and filling being repeated ten times before the mercury was introduced. The tube referring to table B was heated and evacuated and then filled with ordinary room air.

If desired, the apparatus can easily be modified to admit of greater range of pressure change and of volume change. The small cost of construction, the simplicity of design, and the ease of manipulation of this piece of apparatus as well as the importance of the laws it illustrates should recommend it to both the high school and college teacher of physics.

TABLE A.
Moist Air in Tube
Top of Closed Tube 36.85 cm.
Barometer 76.5 cm.

	1 Hg. Closed cm.	2 Hg. Open cm.	3 t°	4 T°	5 P	6 V	7 PV/T
1	21.75	30.65	25.8	299.0	85.4	15.10	4.30
2	21.2	31.2	31.3	304.0	86.5	15.65	4.35
3	20.7	31.7	36.2	309.0	87.5	16.15	4.57
4	20.2	32.25	41.8	315.0	88.55	16.65	4.70
5	19.9	32.6	44.5	317.5	89.2	16.95	4.76
6	19.3	33.15	50.5	323.5	90.3	17.55	4.92
7	18.95	33.6	56.5	329.5	91.15	17.90	4.96
8	18.55	34.0	60.0	333.0	91.95	18.30	5.05
9	17.95	34.6	65.8	339.0	93.15	18.90	5.20
10	17.45	35.15	70.3	343.0	94.2	19.40	5.32

TABLE B.
Room Air Dried by Heating and Evacuating Tube
Top of Closed Tube 59.7 cm.
Barometer 76.5 cm.

	1 Hg. Closed cm.	2 Hg. Open cm.	3 t°	4 T°	5 P	6 V	7 PV/T
1	43.95	45.5	22.5	295.5	78.05	15.75	4.17
2	43.7	45.8	30.0	303.0	78.6	16.0	4.15
3	43.6	45.9	38.0	311.0	78.8	16.1	4.08
4	43.5	46.0	42.0	315.0	79.0	16.2	4.03
5	43.2	46.3	50.5	323.5	79.6	16.5	4.07
6	43.15	46.5	54.0	327.0	79.85	16.55	4.05
7	43.0	46.7	60.0	333.0	80.2	16.7	4.02
8	42.85	46.8	63.0	336.0	80.45	16.95	4.06
9	42.35	47.35	74.0	347.0	81.5	17.35	4.07

TABLE C.
Air Dried by Bubbling Through H_2SO_4
Top of Closed Tube 98.9 cm.
Barometer 75.8 cm.

	1 Hg. Closed cm.	2 Hg. Open cm.	3 t°	4 T°	5 P	6 V	7 PV/T
1	85.9	89.9	34.8	307.8	79.8	13.0	3.38
2	85.7	90.05	40.3	313.3	80.1	13.15	3.37
3	85.65	92.25	45.0	318.0	80.4	13.25	3.35
4	85.5	90.4	50.0	323.0	80.7	13.4	3.35
5	85.35	90.5	55.0	328.0	80.95	13.55	3.358
6	85.25	90.7	60.0	333.0	81.25	13.65	3.33
7	85.1	90.9	66.0	339.0	81.6	13.8	3.325
8	84.95	91.05	70.0	343.0	81.9	13.95	3.332
9	84.75	91.25	76.0	349.0	82.3	14.15	3.335
10	84.65	91.4	80.0	353.0	82.55	14.25	3.335
11	84.55	91.55	85.0	358.0	82.8	14.35	3.32
12	84.35	91.75	90.0	363.0	83.2	14.55	3.34

SOME PRACTICAL PROJECTS IN TEACHING PHYSICS.

BY C. F. PHIPPS,

Northern Illinois State Teachers College, DeKalb, Ill.

Physics deals with so many things connected with our home, school and community life, that if it is presented in a practical, rather than the usual cut-and-dried way, it is both interesting and instructive to our youth. Half a century ago there were fewer inventions and up-to-date conveniences, so the people of both city and farm were able to become acquainted with the limited number of things belonging to the field of science. The few conveniences then were learned easily at home, and the people were relatively more efficient than now. But inventions during the last half century have multiplied so rapidly that the home has been unable to keep up with them, so that the burden of making our youth efficient has fallen more and more upon our schools and colleges. Those institutions as a whole are failing in much of this efficiency work.

Listen to some of the adverse criticisms of science teaching that are offered: "School work, especially in science, is too artificial—not real." "Most of the science subject-matter taught remains unused, both in and out of school and college hours and in after school years." "The big problem of the school is that there is very little relationship between the work of the school and the work of the world." "Our physics books are too much on the order of encyclopedias or dictionaries, and their proper function is for reference only." "We lack books for high school and college which present science as living projects." "The basic

error in science teaching today is that it does not center itself about the interests and desires of the students."

One of the professors in Columbia Teachers College asks and answers this question: "Why do we, as mature people, go to the literature of the automobile company to learn about the workings and methods of repairing of our batteries, and to make other repairs, rather than to a physics text book? Simply because the company's literature satisfies us, and explains in a practical, instructional way the workings of the battery and other parts, and touches closely and appealingly to the project we have." "We must remember," he adds, "that students are immature men and womem and do not enjoy studying dry, unrelated facts, principles, theories and fundamentals any more than we would."

Why not bring small samples of real life and real workable problems to the school and college more than we do, and give them as projects,—those which will appeal to and grip the students? This will not only interest them and show the worthwhileness of physics, but it will develop their thinking power. Dewey says that "there is no thinking without a problem. When judgment is challenged to face a dilemma it makes a fork in the road and thinking begins here."

I grant you that there are difficulties in the way of teaching by the project method, such as large classes, lack of suitable projects, the time factor in the teacher's and student's busy life, lack of trained teachers, lack of equipment and supplies, etc. Yet many science teachers in high school, normal school and college are doing work of this kind, and our plea now is for many more teachers to tackle the problem and thus give students worth-while opportunities of studying science in practical ways.

Since time for this paper is so limited, I will confine myself to one phase of work in physics, namely, some practical projects in electricity. A few years ago while teaching a small class of high school boys we took up some projects in electric wiring. Several small, roughly boarded rooms in the manual training department served our purpose. Only three sides and ceiling were boarded, leaving the front of each room open. In these rooms the students worked out in detail a number of projects in electric wiring of homes, such as door bells, call bells and lighting. The interest was keen, thinking was stimulated, and the results educationally were good, even though not all of the indvidual work was neat and perfect. At other times practical electric burglar alarms for windows were worked out and some students installed them in their homes.

Electric dry cells are easily made, though they may be weaker than boughten ones, by taking apart old dry cells and using the zinc container and carbon stick, and packing a new, pasty mixture of chemicals around the carbon rod in this container. This gives the student an intimate knowledge of the construction of such cells. A strong wet cell, which students enjoy making and using, can be constructed with a cup of water in an eight-ounce bottle, a teaspoonful of potassium bichromate and a tablespoonful of sulphuric acid. Carbon and zinc rods, with wires attached, complete the cell.

With such cells a usable medical battery, or shock coil, can be constructed, using a simple switch, a buzzer for make and break, and two pieces of coiled metal attached to wires to hold in the hands.

A miniature home lighting system is a good project. It is made by mounting several sets of lamp sockets on short boards, each set representing a separate circuit in the house, and these all connected to the main line with switch and fuse plugs. If a watt-hour-meter is at hand the cost of using each lamp or circuit may be ascertained by the students.

Again, the students may mount more lamp sockets on a board, having adjustable connections or switches between them so that the sockets may be cut out or cut in at will, and thus a handy lamp bank is ready for a number of experiments.

Since students occasionally burn out valuable instruments by using wrong connections, they ought to equip themselves with a small fool-proof switchboard which tells at once whether their connections are right or wrong. Having learned the right connections to make with this small switchboard, practically all danger of burning out valuable instruments is avoided.

After electromagnets have been made and tested our students have put them to practical use by making simple telegraph sets and sending messages to each other, either in the laboratory or by installing the sets in their homes.

The making of induction coils, spark coils and other parts of wireless outfits are good projects. Not only do students of physics make most of their wireless apparatus, but boys who never have had physics are doing it. I feel sure that anyone present can relate instances of keen interest shown by students when allowed to make, or assist in installing, a wireless in the school, or when making their own outfit at home.

To mention briefly a few other practical projects in this branch of physics, I will suggest that the electroplating project such as copper plating and nickel plating, be given. Let the students assemble the apparatus and actually plate things. Electrolytes and ionization are taught much more easily after a first-hand acquaintance with electroplating. Different solutions made with distilled water, using in turn salt, acid, sugar and glycerine, may be tested for conducting power, thus showing ionizing and non-ionizing substances.

Why not begin the study of the storage battery by having the students construct simple ones with pieces of lead, a pint fruit jar and dilute sulphuric acid? After charging and testing this storage cell by ringing bells, the construction and workings of the regular battery will be understood more easily.

Interest and profit are gained by having students make Geissler tubes out of old electric light bulbs. The glowing, rarefied gas in such bulbs stimulates interest in another line, and may well lead to the mysteries of X-Ray production.

Making arc lights, using home-made electromagnets to draw the carbon sticks apart when the current is turned on, teaches the principles involved in street lights and lights used in stereopticon lanterns.

Continuing from this the electric furnace may be constructed, using electric light carbons enclosed in hollowed-out fire brick, or in a box lined with some refractory material.

Recently our students obtained some wire of high resistance and worked out a number of interesting projects. One was an electric heater, capable of heating a small room. A piece of sheet aluminum was cut and shaped into a reflector, and the heating wire, wound around an asbestos covered porcelain tube, was mounted in front of the reflector. Some more of the same wire, mounted in six separate coils in the bottom of an asbestos lined shallow box with metal top, made a serviceable heater that could be used as a foot-warmer, or moderately hot stove or toaster. One student wished to make an electric flat iron. He did so by using some of this resisting heating wire inclosed between suitably insulated pieces of lead for weight. He covered it all with sheet copper, and fastened on a wooden handle. When connected to a 110-volt circuit it worked well. Surely college and high school students are interested and benefited in doing such practical work.

A little more ingenuity is required for making a Tesla Trans-

former which will give a 6- to 8-inch spark, but our students have done it after having had an introductory course in electricity.

When other projects are scarce a little time may be profitably spent in making blue print paper and then taking permanent pictures of magnetic fields about magnets and about current bearing wires. Also simple detecting galvanoscopes, electroscopes and electrophorouses may be made by students and experiments performed by using them in preference to elaborate and expensive apparatus.

I will mention in closing one other example of project work, and that is in the field of repair work. When some apparatus is out of order, if it is not too delicate and complicated, we give it to capable students to repair. They enjoy such work and often get much out of it, since they must learn how the apparatus is constructed and the principles by which it works. To mention a concrete case—we have an electric washing machine in our laboratory for demonstrating one use of the motor, and some time ago it failed to work properly. Some students took the motor off the machine, dissected it and found that a loose screw had caused a short circuit and partly burned out the armature. Since we have not the facilities as yet for winding motors we had the armature repaired at the factory; then the students assembled and installed it on the washing machine, making the rather difficult adjustments with ratchets, and the satisfaction of putting the whole machine in good working order again was worth while.

I am sure that others can suggest many more practical and instructive projects for students to do in the wide domain of physics, both in elementary and advanced work, and those who have done some of this kind of teaching know how it enriches a course, and makes the student exclaim "That was the best science course I ever took. I got lots out of it."

THE WAVE FORM OF AN ALTERNATING CURRENT.

By J. C. Jensen,

Nebraska Wesleyan University, University Place, Nebr.

It is often desirable, both as a matter of routine and for purposes of research, to know the wave form of an alternating current supply. In this connection the advanced engineer will immediately think of the oscillograph because of its ability to make a photographic record which may be examined at leisure. But the oscillograph is a costly and complicated instrument which is

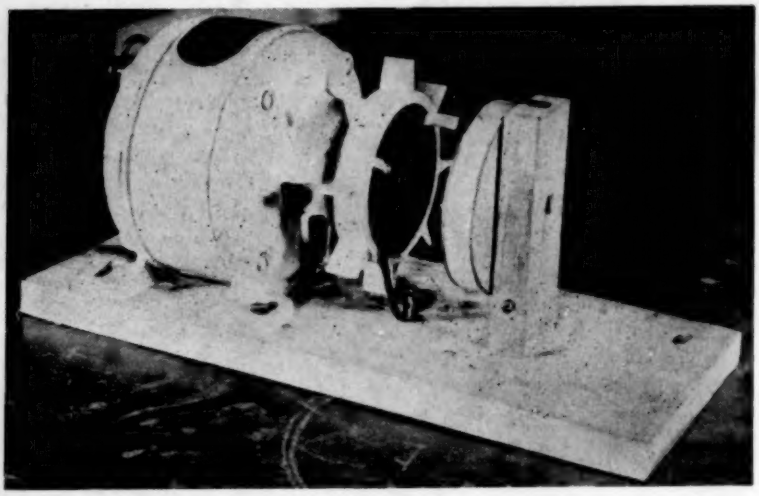


Figure 1.

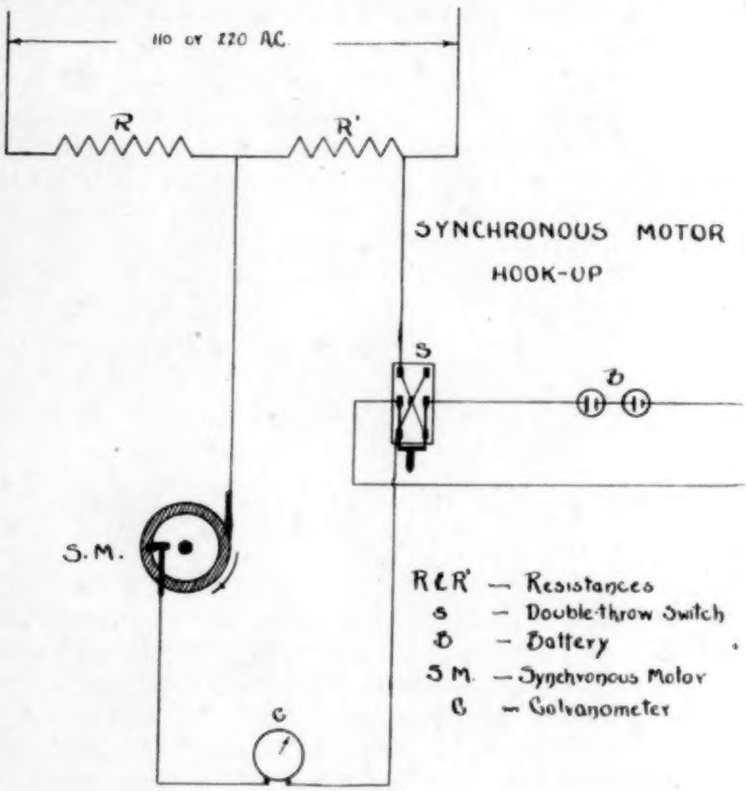


Figure 2.

not always available and the operation of which can be trusted only to the advanced student.

The device known as the Joubert disk, mounted on the shaft of a synchronous motor, has long been in use where it was desired to determine accurately the wave form and upper harmonics of alternating currents of commercial frequencies. Ever since using such a device in connection with a research problem (*Physical Rev.*, Nov. 1916) it has been the desire of the writer to adapt the method for laboratory use in electrical measurements, but he has been unable to do so because of his inability to purchase a synchronous motor at a reasonable price. Within the last year, manufacturers of radio-telegraph apparatus have designed a motor for driving a rotary spark discharger which can readily be adapted for use in connection with wave form measurements.

Figure I shows a photograph of the motor and rotary spark gap. The points and ring of the latter are made of aluminum, mounted on a phenol fibre disk. A small phosphor-bronze strip, making metallic contact with the ring, extends radially one inch

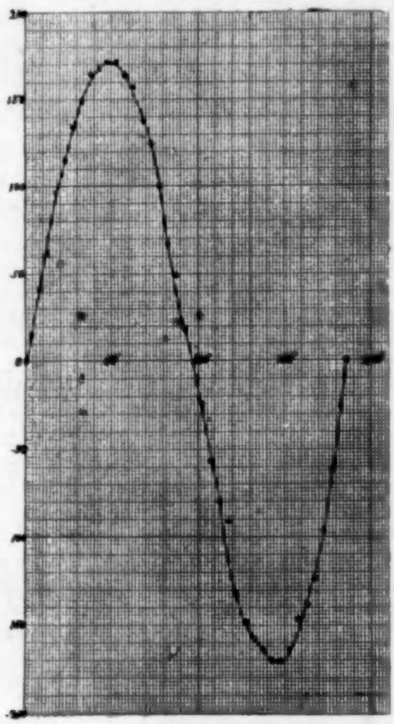


Figure 3.

toward the center. This strip is countersunk in the fibre and held in place by two small bolts. The stationary brush shown in the picture is attached to the base block and makes contact with the ring. The other brush is attached to a wooden disk 360 mm. in circumference and capable of rotation about its axis. The wooden disk is supplied with a millimeter scale and index for setting to definite positions on the cycle. A simple calculation will show that since the motor runs 1800 R. P. M. on a 60-cycle supply there will be two cycles per revolution of the spark discharger, and motion through 180 mm. on the index scale will give the series of instantaneous contacts corresponding to one complete cycle.

In Figure II, is shown the wiring circuit employed. It is evident that for any given setting on the index, the galvanometer deflection being zero, the momentary potential is given by the equation, P. D. = $\frac{(R+R')E}{R'}$. For a 110-volt circuit the sum of the resistances R and R′ should be about 20,000 ohms or sufficient to keep the current within the limits of safety required by the coils. If higher resistances are available, the method may be employed equally well for higher potentials such as checking the wave form on the secondary of a commercial 2,200 volt transformer. The galvanometer used is of 80 megohms sensibility and the battery a Clark or Weston cell. Figure III, shows a curve obtained by a student using the above method.

A NATURALIST IN THE GREAT LAKES REGION.

That the ice-sheet formed during the great glacial period in North America finally melted and retreated farther north, leaving between the Valparaiso moraine and the front of the glacier a lake now called Lake Chicago, is part of the fascinating scientific story written by Dr. Elliot R. Downing in *A Naturalist in the Great Lakes Region* to be published by the University of Chicago Press April 1. This lake stood at one level for a long time, long enough for its waves to eat into the hills along its shores and deposit extensive beaches of sand, just as Lake Michigan is doing now along its present shore line. These beaches stand at a level some sixty feet above the present lake-level, and it is by following these plainly marked beaches that the position of the shore line of early Lake Chicago is determined.

The development of the Dunes and their plants and animals, the climax forest and its predecessor the oak-hickory type, the change of lake to forest or prairie, and the sources of the region's fauna and flora are among the phases of the region discussed in the book, which will be of absorbing interest not only to students and teachers but to motorists, scout-leaders, and nature-lovers generally.

With 450 illustrations and fourteen uniquely illustrated large initials introducing the various chapters, the book is especially artistic, and being of pocket-size in flexible binding is especially convenient.

A 3000-VOLT LEAD PLATE SHOP-MADE STORAGE BATTERY—ITS CONSTRUCTION AND CHARGING CHARACTERISTICS.[1]

By Professor C. T. Knipp and R. J. Ruedy,

University of Illinois, Urbana, Ill.

In the modern, well equipped physics laboratory, whether in secondary school or university, sources of direct high electromotive forces are becoming increasingly more important. It is not the object of this paper to enumerate the uses of such potentials, but rather to describe in some detail a battery of 3000 volts that was built during the past winter by one of the writers and which is now in commission and is giving excellent service. This battery is a shop-made one, meaning thereby that the complete installation, i. e., the lead plates, multiple switches for charging and discharging, binding posts, and the cupboard in which the cells are assembled, were all made in our physics shop. The 1500 test tubes necessary were especially blown by the Central Scientific Company, Chicago.

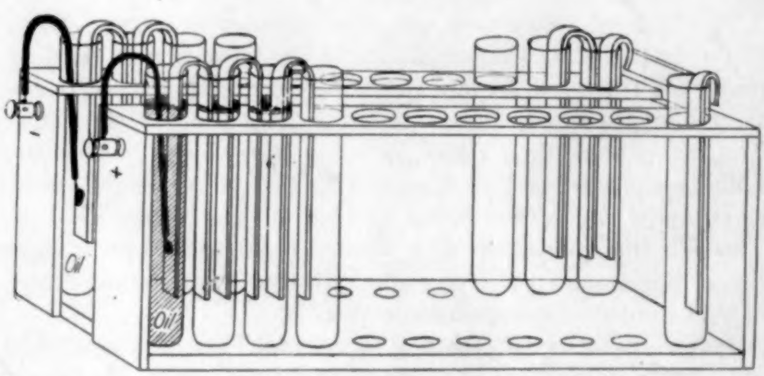


Fig. 1 Tray of 20 Test Tube Cells Connected in Series

The cells are grouped in trays of 20 each, and thus each tray has a potential, when fully charged, of 40 volts. The trays are constructed of wood and in appearance are similar to a test tube rack as may be seen in Fig. 1. Each tray was boiled in paraffine for 15 to 20 minutes. After cooling it was dipped again in paraffine so as to thoroughly protect the wood from the acid, and also to improve the insulation.

Each individual cell consists of a glass test tube, 2.5 to 3 cm. in diameter, about 13 cm long, in which are placed two strips

[1]Read at the spring meeting of the Illinois Academy of Science at Rockford, April 28, 1922.

of sheet lead and a quantity of dilute sulphuric acid. To protect the electrolyte from evaporation, it is covered with a thin layer of oil, which also tends to prevent the acid from being thrown off in spray while charging the battery. A general idea of the wooden tray and assembled cells may be obtained from Fig. 1. The purpose of the two auxiliary tubes, next to the binding posts and filled with oil, is to prevent the acid from creeping. The oil also protects the soldered joints.

The plates were made of sheet lead 3 mm. thick. After cutting it into strips of the desired width, they were run through two corrugated rollers, giving them somewhat more surface, and also providing recesses to hold the active material formed in charging. These strips were then cut into the desired length, each length providing two plates, when bent into shape. The strip thus bent was placed astride two cells, one plate forming the positive electrode and the other the negative of the adjacent cell. The lead plates being heavy but little warping will result, hence no separators are necessary.

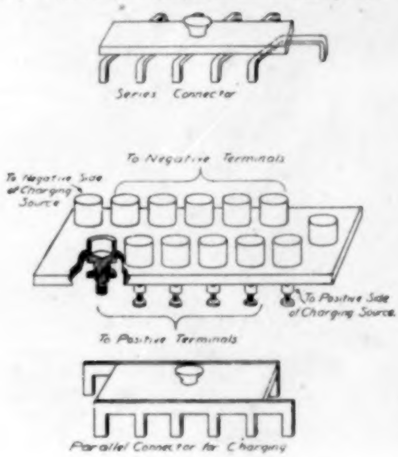
The manner of putting the cells together is clearly shown in the figure. The time required for the formation of the lead plates may be considerably shortened by treating them before assembling in strong nitric acid for from four to six hours. The plates were then rinsed in water and placed in position. Dilute sulphuric acid of density 1.25 to 1.30 was used as the electrolyte, and a protecting film of oil was placed over it. The cells thus assembled were allowed to stand for several days before beginning to charge them. During this interval a coat of lead sulphate formed on the plates.

In the formation of the plates, a small current (about 1-10 of an ampere) was sent through each cell. Larger currents caused excessive bubbling which is objectionable since it tends to prevent the formation of active material on the plates. The charging was allowed to continue until they were all gassing freely, which required about 8 hours.

The charging source was then disconnected, and the cells discharged through a resistance at a rate about equal to that of charging. After they were discharged, the cells were allowed to stand for a day and then charged as before, but now in the opposite direction, forming lead peroxide on the plate which had previously been negative. When the cells were again gassing freely, the same procedure as before was followed in discharging them. The above cycle was then repeated until

they seemed to have reached their maximum capacity. About 15 such cycles were required, after which they were charged and discharged a few times *without reversing the polarity,* and after a final charge were put into use.

In charging the cells, the trays containing them were always placed in parallel, thus the charging voltage necessary was but little in excess of that of each tray. Since there are twenty cells in each tray, the charging voltage need not exceed 45 volts. However, to obtain a high voltage on discharge when using them, the trays must be connected in series. Thus five trays, when fully charged give when connected in series, 200 volts.



MULTIPLE SWITCH

FIGURE 2.

To facilitate the changing of connections, a multiple switch was constructed (Fig. 2) which accommodates 5 trays, the number assembled on each shelf of the cupboard. The terminals of each tray are brought to a pair of mercury cups, as indicated in Fig. 2. The positive terminals are connected to the front row of cups, and the negative to the back row. The leads from the charging source are connected to the two end cups as shown. Two types of connectors are used, which consist of copper or brass legs attached to a block of hard rubber. The legs are arranged to set in mercury cups. The one type has all of the legs on the front side connected together, and likewise on the back, so that when it is inserted the trays are all connected in parallel,—positive all together on the front and negative on the back. The other type has the legs connected

across diagonally so that when the connector is in place the positive terminal of one tray is connected to the negative terminal of the next and so on. One multiple switch is provided for each shelf of five trays. In order to connect the different shelves together in series diagonal cross wires are used. These wires show in Fig 3.

FIGURE 3.

The particular installation which is the subject of this paper, consists of 1,500 cells, or 75 individual trays assembled in three tiers of 25 trays each. The total potential when all are in series and fully charged is 3,000 volts. In order to reduce any leakage to a minimum value, the five trays on each shelf are supported on an individual paraffined shelf, which in turn is supported by four porcelain insulators. In this way each 200 volts is thoroughly insulated from the cabinet as a whole. An idea of this method of assembling may be obtained from Fig. 3.

In building such a battery, it is, of course, not essential that the cells be grouped as described. Almost any number of individual cells may be incorporated in one tray, but it seems that for maximum convenience, twenty cells to a tray is about the right number, for if more are added the tray becomes large and heavy.

The current capacity of such a battery is naturally very low.

It should be used primarily for potentials only, or for very small currents of the order of a few milliamperes. The cells will, however, deliver about 1-10 ampere, but for a short time only, the voltage soon dropping off. Cells constructed of sheet lead and formed as these should be charged regularly once per week whether they are used or not. For convenient charging the trays should be mounted in a cupboard as described, where the individual trays may be returned for charging. If preferred, the cupboard may be replaced by three cabinets of 1,000 volts each mounted on rubber tired castors, thus making the battery available in different rooms.

DUST SPIRAL NEAR FLAGSTAFF, ARIZONA.

By Ferdinand W. Haasis.

At 1:15 or 1:20 p. m., on June 19, 1920, the writer's attention was attracted by a peculiar sound suggesting an automobile motor. Heard out of doors, the sound resembled the tearing of coarse paper.

Above the forest, due west of the Fort Valley Experiment Station, nine miles northwest of Flagstaff, a column of tawny dust, the color of the dry soil at that time, was seen traveling in an easterly direction, though with minor deviations, and forming a somewhat undulating band in the general direction of the sun. From below it appeared to be a nearly vertical spiral so close to the sun that the upper part could be seen only with great difficulty. The column was intermittent, sometimes almost wholly disappearing, at which time the characteristic noise subsided also. The height was difficult to estimate; perhaps 500 feet, perhaps 1,000.

When about 500 feet west of the west fence of the station grounds it broke off to the southeast downhill, and whirled around near the back corral. It oscillated on this flat for a time, apparently moving first southeast, then northwest, possibly in a circle, or in other directions. At one time it seemed to be starting to move north or northeast directly toward the station buildings. The basal diameter, judged from a distance of about 300 feet, was from 10 to 15 feet. Leaves and trash were included in the swirl for a height of not less than 5 or 10 feet, resulting in a dense blackish cloud to this height. Had the whirl been observed from above, its rotation would have appeared counterclockwise. When south of the observer the column still seemed to lie in the general direction of the sun, although probably mainly *ahead* of the position of the ground end.

The spiral died out on a rocky point about 500 feet south of the back corral at about 1:25 p. m., the upper part of the dust column floating for some time after the ground swirl had disappeared.

The wind about noon had been variable—northwest, north, northeast, and east. The northwest and east winds are less common here than those from other directions. At about 1:25 p. m., there was almost no wind on the station grounds. The day was clear and hot with a maximum shade temperature of 81° at 2 p. m., and 80° at the time of the phenomenon.—*Monthly Weather Review.*

PROBLEM DEPARTMENT.

CONDUCTED BY J. A. NYBERG,
Hyde Park High School, Chicago.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and solve problems here proposed. Problems and solutions will be credited to their authors. Each solution, or proposed problem, sent to the Editor should have the author's name introducing the problem or solution *as on the following pages.*

The Editor of the department desires to serve its readers by making it interesting and helpful to them. If you have any suggestion to make, mail it to him. Address all communications to J. A. Nyberg, 1039 E. Marquette Road, Chicago.

LATE SOLUTIONS.

733. *Smith D. Turner, Andover, Mass.*

SOLUTION OF PROBLEMS.

736. *Proposed by J. T. Crawford, University of Toronto, Canada.*

A geometric and a harmonic progression have the same pth, qth, and rth terms, a, b, and c, respectively. Prove

$$a(b-c)\log a+b(c-a)\log b+c(a-b)\log c = 0.$$

Solution by L. R. Kellam, Culver Mil. Acad., Culver, Ind.

From the G. P. we derive $a=AR^{p-1}$, $b=AR^{q-1}$, $c=AR^{r-1}$ or $R^{p-q}=a/b$ and $R^{q-r}=b/c$. Then $(p-q)\log R=\log a-\log b$, $(q-r)\log R=\log b-\log c$, or (1) $(p-q)/(q-r)=(\log a-\log b)/(\log b-\log c)$.

From the H. P. we derive $1/a=x+(p-1)d$, $1/b=x+(q-1)d$, $1/c=x+(r-1)d$, and from these equations derive (2) $(p-q)/(q-r)=c(b-a)/a(c-b)$.

Combining equations (1) and (2), we get the desired result.

Also solved by *T. E. N. Eaton, Redlands, Calif.,; J. B. Faught, Yankton College, So. Dak.; J. F. Howard, Brackenridge H. S., San Antonio, Texas; Edna E. Kramer, student, Hunter College, New York; H. Lazott, Worcester, Mass.;* and the following pupils of the *Redlands H. S., Calif.: Ralph Cope, '23; John Ide, '23; Homer Joy, '25; Reva Rose, '25.* The editor feels sure that the readers of the department would like to hear how Mr. Eaton manages to teach progressions and logarithms to a freshman class.

Comparing problems 713, 731 and 736, we note that this relation is true for an A. P. and a H. P. only if the qth term is half way between the pth and rth, and that for an A. P. and a G. P., the relation is

$$(b-c)\log a+(c-a)\log b+(a-b)\log c=0.$$

737. *Proposed by Henry L. Wood, Boonton, New Jersey.*

Without using parallel lines, construct the fourth proportion to three given lines, a, b, c.

I. Using the theorem about the segments of two chords in a circle, the problem was solved by *J. F. Howard; Hazel C. Jones, Hammond, Ind.; H. Lazott; Isabel McCoy, pupil, North East H. S., Kansas City, Mo.; Edw. A. Ravenscroft, pupil, New Trier Township H. S., Kenilworth, Ill.; Smith D. Turner.* Using the theorem about the segments of two secants, by *Iram Luelleman, Mattoon, Ill.; G. H. Crandall, Culver Mil. Acad., Ind.* Using the theorem about an inscribed triangle, and altitude, and a diameter, by *I. Luelleman.* Using two similar triangles, by *L. R. Kellman; Claude Nunnally, pupil, Chester Agriculture H. S., Va*

II. *Solution by John B. Faught, Yankton College, Yankton, So. Dak.*

On a line take $AB=b$, $BC=c$, so that $AC=b+c$. On AC as a diameter, draw a circle and erect a perpendicular to AC at B, meeting the circle at D. Then $BD^2=bc$. From B lay off on the given line $BE=a$. Draw a circle through D and E having its centre on AC, and call F its intersection with AC. Then $BF=x$ is the required line. For $BD^2=ax$, and hence $ax=bc$, or $a:b=c:x$.

Similarly solved by F. A. Cadwell, St. Paul, Minn.

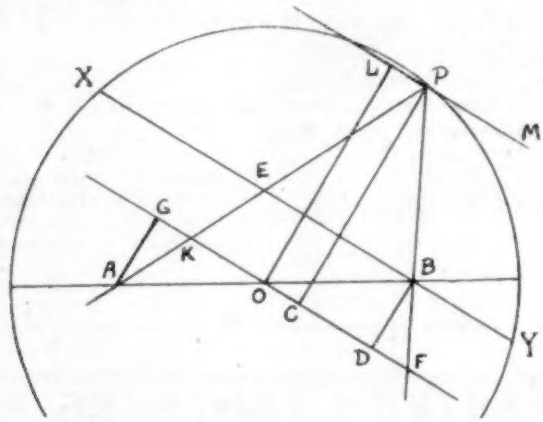
III. The *Proposer* has sent in two interesting solutions due to *E. Daniele of Pavia*, and *E. Dubois.*

1. Draw two concentric circles of radii a and b respectively. On the first circle choose points A, and B such that AB $=c$. With A and B as centers and any fixed radius, cut the two circles in A^1 and B^1. Then A^1B^1 will be the fourth proportional, because $\triangle$s A^1OB^1 and AOB are similar.

2. Draw a circle of radius a, and on it choose the points A, B, C so that AB $=b$, BC $=c$. From B draw a perpendicular to AC and extend it its own length to D. Then BD is the fourth proportional because $\triangle$s BCD and BOA are similar, O being the center of the circle.

738. *Proposed by J. F. Howard, San Antonio, Texas.*

A and B are points on a diameter and equidistant from the center XBY is any chord through B. P is any point on the circumference. PA intersects XY in E. Can the point P be selected so that PBE will be an isosceles triangle?



Solution by the Proposer.

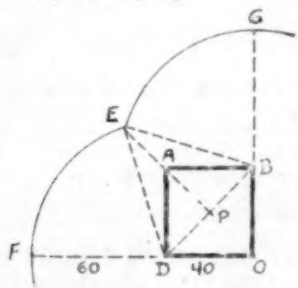
Suppose P is the required point. Draw GF and PM‖XY. Draw PC bisecting <RPB, hence $\perp$XY, GF, PM. Draw OL‖PC; BD, through B, ‖PC. Extend PB to meet GF at F. Draw AG$\perp$GF.

Then KC $=$ CF(since $\triangle$PCK $=$ $\triangle$PCF). AG $=$ BD(since $\triangle$AOG $=$ $\triangle$BOD), and OD $=$ OG. GK $=$ DF (since $\triangle$AGK $=$ $\triangle$BDF). Then CF $=$ CK, or OD $-$ OC $+$ DF $=$ OC $+$ OG $-$ GK. Putting DF $=$ GK, we now have DF $=$ OC $=$ GK.

From the similar $\triangle$s, BDF and PCF, DF/CF $=$ BD/PC. In this proportion, put DF $=$ OC, CF $=$ OD, PC $=$ OL, so that

$$OC \times OL = OD \times BD$$

also $(OC)^2 + (OL)^2 = (OP)^2$. Since, OD, BD, OP, are



known lines we can use these equations to find OL. And when OL is found, L is determined, and thereby the point P.

This problem arose from the study of problem 712, (see March, 1922),

AB is the base of the triangle, the radius of the circle is the median, and $<ABX$ is half the difference of the base angles. $\triangle ABP$ is then the required triangle.

739. *Proposed by Ethel E. Barneby, Twin Falls, Idaho.*

ABCD is a square barn, 40 feet on a side. A cow is tied at A with a rope 100 ft. long. Over how much ground can the cow graze?

Solution by Smith D. Turner, Andover, Massachusetts.

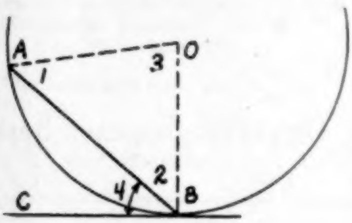
The area of three-fourths of the circle is 23561.945 sq. ft. Cos $<EDP = 20\sqrt{2}/60 = \sqrt{2}/3$; $<EDP = 61°52'30''$; $<EDF = 73\frac{1}{8}°$. Hence the area of the 2 sectors is 4594.590.

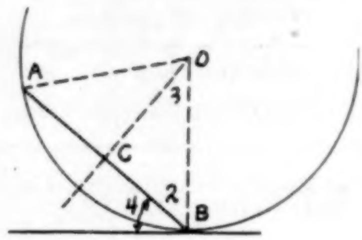
The area of $\triangle EDB = 400\sqrt{14} = 1496.663$; but from this we subtract the area of $\triangle ADB$, or 800, leaving 696.663. Hence the final area is 28853.2 sq. ft.

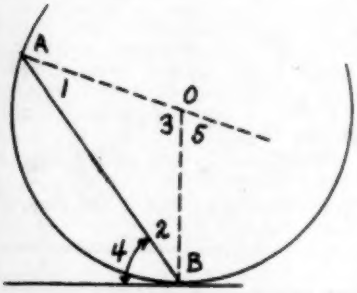
Also solved by *T. E. N. Eaton; J. F. Howard; E. Tabor, Upper Lake, Calif.; Edw. A. Ravencroft; H. L. Wood.*

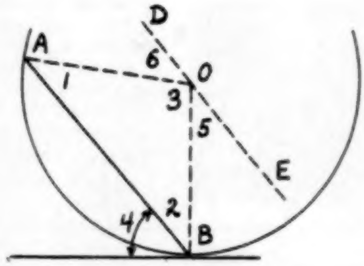
740. *For high school students. Proposed by N. L. Roray, Metuchen, N. J.*

Give as many proofs as you can of the theorem? An angle formed by a tangent and a chord drawn through the point of contact is one-half the central angle of the chord.









In most of the proofs received, the pupil had assumed the theorem which states that an angle formed by a tangent and a chord is measured by half the intercepted arc. But this is the very theorem which is to be proved. Briefly, some of the proofs were:

I. *Proofs by Isabel McCoy, North East H. S., Kansas City, Mo.*

In figure 1

$2<2 \times <3 = 180°$

$2<2 + 2<4 = 180°$

$\therefore <3 = 2<4$

In figure 2, $OC \perp AB$

$<2 + <4 = 90°$

$<2 + <3 = 90°$

$\therefore <4 = <3 = <AOB/2$

II. *Proofs by Ruth Coon, Anthony H. S., Anthony, Kansas.*

In figure 3

$<2 + <4 = \frac{1}{2}(<3 + <5)$

$<2 = \frac{1}{2}<5$

$\therefore <4 = \frac{1}{2}<3$

In figure 4, $DE \parallel AB$

$<4 + <2 = \frac{1}{2}(<6 + <3 + <5)$

But $<6 = <1 = <2 = <5$

$<4 = \frac{1}{2}<3$

PROBLEMS FOR SOLUTION.

751. *Proposed by Elmer Schuyler, Bay Ridge H. S., Brooklyn, N. Y.*
Find the value of

$$\sin [2\cos^{-1} \{ \tan(3\cot^{-1}x) \}]$$

752. *Proposed by Walter R. Warne, Syracuse University, Syracuse, N. Y.* The sum of n terms in two Arithmetic Progressions are respectively $n\,(n+1)$ *and* $\frac{1}{2}n\,(\frac{1}{2}n-1)$. Determine if they have any common term.

753. *Proposed by G. H. Crandall, Culver Military Academy, Culver, Ind.*
Given two points, A and B, on the same side of a plane, and at distances a and b from the plane. The distance between the projection of A and B on the plane is d. Find the locus of a point P on the plane such that the lines PA and PB are equally inclined to the plane.

754. *Proposed by Smith D. Turner, Andover, Mass.*
Given $\triangle$ABC and a point P outside the triangle. Required to draw a line through P bisecting the triangle.

755. *For high school pupils. Proposed by the Editor.*
A goldsmith charged 2% commission when purchasing some gold from A, and 2% when he sold the same gold to B. But he made $25 extra in the deal by cheating, as he bought with a weight which was one ounce too heavy, and sold with a weight which was one ounce too light. How much did A get for the gold?

CONCENTRATED DEVELOPERS.

The term, "concentrated developer," is a very broad one, says a German contemporary; for, sometimes, so-called concentrated solutions when diluted with three times their volume of water will not develop a plate in the time a normal solution should. Comapratively few developers permit the preparation of highly concentrated, durable solutions owing to the nature and solvent properties of the developing substance itself.

In order to test the quality of an unknown concentrated developer we must have a basis for comparison, such as rodinol or pyrocatechin-caustic soda, and find out how the diluted solutions act and the quality of the resulting negative or print in comparison with other standard developers. We must observe the time required by different degrees of dilution, how often they may be used without perceptible deterioration in the gradation and strength of the negative or print.

Highly concentrated developers are usually prepared with caustic soda; but the durability of such solutions is rather brief in practice; but these are usually made with the object of having a stock on hand that will keep good for a long time. Many of the developers sold by the trade are so overloaded that, although they keep fairly well in moderate temperature, cold weather will cause precipitation that cannot always be re-dissolved by warming the bottle.—[*Photo-Era.*

DESENSITISING AN OXIDATION PROCESS.

As yet the action of safranin in desensitising silver-bromide plates cannot be explained theoretically, says Luppo-Cramer in *Photographische Rundschau.* Experiments recently made have shown that, contrary to the view heretofore held, the desensitising is to be attributed to an oxidising effect of the safranin in the presence of light. The latent image may even be bleached out in the presence of certain desensitising dyes! In this way *reversed* pictures are obtained on plates that have been previously exposed diffusely which indicate a strong orthochromatism. It is also a very interesting fact that, after converting a diffusely exposed silver-bromide diapositive into silver-iodide and then coloring with safranin in the light, an excellent bleached-out picture will be had, which shows an extraordinary color-sensitiveness of the silver-iodide. This optical sensitising of the silver-iodide, which is brought about by the reversing of the normal process of exposure, is all the more striking because never before has the color-sensitising of silver-iodide worth mentioning been obtained. The entire process is most interesting.—[*Photo Era.*

ARTICLES IN CURRENT PERIODICALS.

American Journal of Botany, for March, *Brooklyn Botanic Garden*. *$6.00 per year, 75 cents a copy*. "Undercooling of peach buds," Earl S. Johnston; "Significance of the Behavior of Sensitive Stigmas," F. C. Newcombe; "The Relation of Age to Size in Certain Root Cells and in Vein-Islets of the Leaves of Salix Nigra Marsh," Marjorie A. Tellefsen; "The Origin of New Varieties of Nephrolepis by Orthogenetic saltation," "II. Regressive Variation or Reversion from the Primary and Secondary Sports of Bostoniensis," R. C. Benedict.

Condor, for March-April, *770 South Pasadena Ave., Pasadena, Calif.*, $2.00 *per year*. 40 *cents a copy*. "A Large Tern Colony in Texas" (eleven photos), J. R. Pemberton; "Notes on Fox Sparrows in California in the Autumn of 1921," Joseph Mailliard; "A Study of Roosting Holes of the Red-shafted Flicker" (three illustrations), Emerson A. Stoner; "A Law Governing the Elevation of the Nesting Site," Charles Ketchum Averill.

Education, for April, *120 Boylston Street, Boston*, $4.00 *per year*, 40 *cents a copy*. "The Triune Mr. Burroughs," James C. Bowman; "Moral Education" (second paper), Susan W. Norton; "The Junior High School and the Drama," M. B. Jaslow; "The High School Mathematical Requirement," G. V. Price; "Relating Geography to Vocational Enlightenment," Olive Nolan; "The Rating of Principals and Superintendents," Stephen G. Rich.

Geographic Review, for April, *Broadway at 156th St., New York City*, $5.00 *per year*, $1.25 a copy. "Eskimo Art," (18 drawings), Diamond Jenness; "The Geographical Names Used by the Indians of the Pacific Coast," (1 map, 4 photographs), T. T. Waterman; "Tides in the Bay of Fundy," (1 map, 2 diagrams, 3 photographs), H. A. Marmer.

"The Forests of the Dominican Republic," (2 maps, 6 photographs), William D. Durland; "Geographical Relations in the Development of Cuban Agriculture," (3 maps, 4 diagrams), R. H. Whitbeck; "Geographic Factors in the Relations of the United States and Cuba," (1 map), D. S. Whittlesey; "Prehistoric Geography," (1 map), O. G. S. Crawford; "Some Erroneous Ideas of Arctic Geography," Vilhjalmur Stefansson; "The Geography of History: A Review," Douglas Johnson.

Journal of Geography, for April, *2249 Calumet Ave., Chicago*, $2.00 *per year*, 25 *cents a copy*. "Evaluating Tests in Geography," Edith Parker; "The Seaports of San Francisco, Los Angeles, and San Diego," Jehiel S. Davis; "The Method of Orientation in Teaching Geography," M. Aurousseau; "A Plea for the Average Teacher," Amy Ware; "A Personally Conducted Tour to Japan," Mary Ina Seed; "A Method of Teaching State Geography," Harvey D. Douglass; "Geography—A Social Science," Burton A. Barns.

Nature-Study Review, for March, *Ithaca, N. Y.*, $1.50 *per year*, 20 *cents a copy*. "School Gardens in 1922," Ellen E. Shaw; "The Child and the Forest," Herbert A. Smith; "A School Fair," A. G. Pennell; "Garden Work in Congested Cities," Joseph S. Taylor; "A Capital Idea from the Washington Schools."

Photo Era, for April, *367 Boylston Street, Boston, Mass.*, $2.50 *per year*, 25 *cents a copy*. "Photographing Spring-Creatures," Dr. J. B. Pardoe; "How I 'Shocked' a Plate," William A. Stephan; "Selling Your Photographs," Frederick C. Davis; "Landscape Possibilities Without Foliage," Phil M. Riley; "With Snowshoes and Camera in the Canadian Rockies," Dan McCowan; "Preparing Light-Sensitive Photographic Fabrics. Part IV," Chas. E. Mullin; "Experience That Hampers," William P. Mattern.

School Review, for April, *University of Chicago Press*, $2.50 *per year*, 30 *cents a copy*. "Educational News and Editorial Comment," "Adult Education in the Army," Z. T. Egardner; "A High-School Principal's Self-Rating Card," P. R. Spencer; "New York City Textile High School," W. H. Dooley; "General Plan for a Course in Economics," A. R. Mead.

BOOKS RECEIVED.

Fundamentals of Practical Mathematics, by George Wentworth, David Eugene Smith, and Herbert D. Harper. Pages V × 202. 14 x 19 cms. Cloth. 1921. $1.50. Ginn & Company, Boston.

Intermediate and Advanced Algebra, by Murry J. Leventhal, Stuyvesant High School, New York City. 96 pages. 14 x 19.5 cms. Paper. 1920. Globe Book Company, New York City.

Physics, Including Recent Examination Questions, by M. H. Kessel, Clark School of Concentration, New York City. Pages 91. 15 x 23 cms. Paper. 1920. Globe Book Co. New York City.

Uses of School Assemblies, Lincoln School. Pages 69. 13.5 x 20 cms. Paper. 1922. Lincoln School, Columbia University, New York City.

Modern Business Arithmetic, by Harry A. Fainey, Northwestern University, and Joseph C. Brown, Teachers College, St. Cloud, Minn. Pages VI + 485. 14 x 20 cm. Cloth. 1922. Henry Holt and Company, New York City.

Educational Directory for 1921-22. Bulletin No. 48. 142 pages. 15 x 23 cm. Paper. Washington, Government Printing Office.

BOOK REVIEWS.

Elementary Manual of Physiology, by Russell Barton-Opitz, Columbia University. 411 Pages. 14x20.5 cms. Cloth. 1922. $2.50 net. W. B. Saunders Co., Philadelphia.

This is a splendid book which has come from the press at a very opportune time. It is a book midway between that which should be used by high school students and those in the first year of the university course. And it fits the nitch that has for many years been demanding a book of this character. It surely will do much toward stimulating the study of this most important subject. It is divided into six parts, under the general heads of physiology of muscle and nerve, circulation of the blood and lymph, respiration, nutrition, the nervous system, and the sense organs. The book is splendidly written, diction is almost perfect, and one with any interest in physiology cannot help but become interested in the perusal of the same. There are 40 chapters. Major paragraphs begin with bold face type, the material in bold face type indicating the subject matter to be treated in this particular paragraph. It is printed in ten point type on paper that is not too glossy. There are 147 drawings that have been especially selected for the text. Mechanically, the book is well made. It deserves a wide circulation among first year university and college students.

C. H. S.

Annual Report of the General Educational Board. Pages XI + 129. 13 x 20 cms. Paper. 1921. General Education Board, New York City.

A very complete report of that which this board has accomplished during 1921. It is divided into nine chapters plus the appendices. The resources and appropriations are given. A rather complete discussion is given on professional education, and the relation of the board to the schools. Studies and surveys of different school systems are discussed. Negro education has its share, and a summary of appropriations is also given. The treasurer's report is complete. There is a good index. A report that all interested in general education should read.

C. H. S.

The Earth and Its Life, by A. Waddingham Seers. Pages 108. 13 x 18 cms. Cloth. 1922. World Book Company, Yonkers, N. Y.

A splendid book on general science. A brief account is given of the origin of our earth, including the story of evolution, and culminating in the origin of man. Many facts in the field of geology, botany, and ethnology are given in a very instructive way. The book in a packed form gives the history of the earth down to the present civilization. It is written in a very fascinating way so that anyone reading it cannot help but be interested. While the book does not go into a real scientific theory, the facts given are all based on scientific theory and are correct.

C. H. S.

The Place of the Elementary Calculus in the Senior High-School Mathematics, by Noah B. Rosenberger, Acting Head of the Department of Mathematics in Dickinson College, Carlisle, Pa. Pages vii+81. 15.5 x 23 cm. 1921. Published by the Teachers College, Columbia University, New York.

In this contribution toward the readjustment of the mathematics curriculum of the high school, the author gives an interesting report of his study of the question of calculus in the senior high school and his conclusions. It includes a study of the status of mathematics in the schools abroad that correspond to our high schools, the trend of mathematics in our public school system, an historical survey of the natural growth of calculus in the development of mathematics; comparison of textbooks on elementary calculus for beginners and for self-instruction, and suggestions for a modern presentation of elementary calculus. Only three American textbooks are mentioned in his review, while there are several others which might well be included.

H. E. C.

Practical Business Arithmetic, by Helen J. Kiggen, Instructor in Salesmanship and Business Methods in Continuation Schools and the High School of Practical Arts, Boston, Mass. Pages xi+404. 13x19 cm. 1922. The Macmillan Company, New York.

This book has been prepared particularly for use in continuation schools, pre-vocational classes, trade schools, and high schools offering courses in salesmanship, dress making, and domestic science. The problems are such as arise in the daily work or business surroundings of the pupil. Short methods and checks are emphasized. The work is planned to instil into the minds of the pupils the character-making quality of individual responsibility in money matters, which comes from the practice of thrift, and to show the loss resulting from waste. There are many interesting features in this book which will appeal to teachers.

H. E. C.

Elements of the Differential and Integral Calculus, Second Edition, Revised, by William S. Hall, Professor of Mathematics, in Lafayette College. Pages xiii+250. 15 x 22 cm. 1922. D. Van Nostrand Company, New York.

In this edition, the chapters on definitions and principles, differentials and rates, and integration have been entirely rewritten, and many new problems have been added. Integration is introduced immediately after the fundamental formulas of differentiation have been established. A large number of carefully selected examples, some original ones, and numerous practical numerical problems from mechanics and different branches of practical mathematics are given. The book is well printed on heavy paper, and the matter is well arranged. H. E. C.

Plane Trigonometry, by Leonard E. Dickson, Professor of Mathematics in the University of Chicago. Pages xix+176+35. 16 x 22 cm. 1922. Benj. H. Sanborn and Co., New York.

To emphasize practical applications, to furnish simple and sensible problems which reflect some activity of actual life, and to develop the subject clearly, concretely, and simply are some of the distinctive features of this book. Twenty-three pages are given to the subject of navigation and twenty-one to surveying. In addition to the usual four-place tables there is a traverse table and table of meridional parts.

H. E. C.

Fruit-Growing, by Benjamin Wallace Douglas, former State Entomologist of Indiana, Manager of the large commercial orchard at Hickory Hill, Trevlac, Ind. Pages 344. 13.5 x20 x3.5 cm. Illustrated with many reproductions from photographs taken by the author. Cloth. 1922. $2.50 net. Bobbs-Merrill Co., Indianapolis.

This is a book that every teacher of scientific agriculture should have. The chapter on the soil is especially interesting in this connection. The author does not claim to know all about the use of fertilizers but gives cases of experiments and the results and interprets these results most cautiously. Throughout the book he takes the wise attitude of not pretending to know all that is to be known about fruit, growing and yet he knows and tells a tremendous lot in the book. He also tells it interestingly, and frequently in the vernacular of those who are nearest to the soil. There are bits of humor and flashes of wit at intervals that Mark Twain might have evolved. All this makes the book more readable. The chapter headings indicate the scope of the work locating the orchard, selecting the trees, planting the trees, the soil, pruning, spraying, harvesting and marketing peaches, plums and cherries, grapes, small fruits, apple varieties, peach varieties, plum varieties, cherry varieties, grape varieties. There is an index. Those teachers who have orchard interests, and many have such a hobby, will find this book most interesting and useful, too, in a practical way.

F. B. W.

Civic and Economic Biology by William H. Atwood, State Normal School, Milwaukee. Pages XV+470. 364 illustrations, 14x20 cms. Cloth. 1922. $1.68 net. P. Blakiston's Son & Company, Philadelphia.

It does one all sorts of good to have placed in his hands a text similar to this one. It is so splendidly gotten together that it is indeed a pleasure for the ordinary layman even to sit down to read it, as it is written in such clear language, the diction being so perfect, that he can understand it. The book is written primarily for use in the second year of high school. Its inspiration was secured by association with pupils in this year of high school. The book is divided into seven units in the best possible order, as the author sees it. Each unit is complete in itself, so that it is perfectly possible for an instructor to begin the book with any unit. If there is too much material, it is easily possible for the instructor to omit some of it. The subjects of botany and zoology are nicely discussed and are so related and intermingled that the author is perfectly justified in calling the book one in biology. The major paragraphs begin in bold-faced type, thus indicating the subject-matter to be treated in those paragraphs. There are seventy different chapters, or headings. Each chapter ends with references to field trips and reports and also has some questions appended. It is a book that can be recommended for use in all high schools and is one that all instructors should possess. Principals and superintendents who are considering the adoption of a book on biology cannot do better than to select this one.

C. H. S.

Some Uses of School Assemblies—Lincoln School. Pages 69. 13.5x20 cms. Paper. 1922. Lincoln School, Columbia University, New York City.

As far as the author of this review is concerned, this is the first book that has come from the press treating of school assemblies. Too frequently these assemblies have occurred purely as a matter of amusement, without the idea of any instruction being given. This little book presents a record of certain experiences with school assemblies. It does not necessarily go into complete discussion of the entire question, but it does give information that the school has received since it was founded; and if it can increase the interest of principals and instructors in making assemblies more effective, it will have accomplished the purpose for which it was written.

C. H. S.

Biology by Charles Gramet, Stuyvesant High School, New York City. Pages 112. 15x23 cms. Paper. 1920. Globe Book Company, New York City.

This author has compiled a book in which the fundamentals of elementary biology are presented. All non-essential matter is eliminated, and it is only the very essential subject matter that is discussed. There are twenty-three chapters in the book, and at the end of each chapter is a series of questions that are brought out from that chapter. At the end of the book there are several pages devoted to recent questions in biology. The drawings have been made especially for this work. It is a little book that should be possessed by all biology teachers.

C. H. S.

How to Study Through Physics, by Fernando Sanford, Leland Stanford University. Pages VII +56 2.5 x18.5 cms. Paper. 1922. Macmillan Co., New York City.

A most important little book is this one on, "How to Study." It is very fortunate for all high school pupils especially, that this little book has recently come from the press, because the vast majority of pupils in high school do not know how to study. This has been for a long time a neglected phase of their work. If they were taught how to use their time to the greatest advantage, there is no question but that much time could be saved. This little book tells how to study through illustrations taken from physics. It is a book that demands large circulation, and it seems to the writer that it ought to be in the possession of every high school teacher. It is well written and to the point.

C. H. S.

New Laboratory Manual—a Book of Projects for General Science—by Lewis Elhuff, George Westinghouse High School, Pittsburgh, Pa. Pages VIII+93. 13x19 cms. Cloth. 1921. D. C. Heath & Co., New York City.

In order to meet the requirements in general science as far as the project method of instruction is concerned, this book has been written. There are in the book 117 different projects, enough so that the instructor is able to make a selection to fit the apparatus which he may have in his laboratory. The projects are divided into three parts: demonstrations by the teacher, demonstrations by the teachers assisted by pupils, and individual projects. The best judgment has been used in the selection of these projects. List of apparatus and chemicals for use in the book are given. It is one of the best books of the kind yet from the press. The author advises all instructors in general science, who wish to use the project method, to secure this book. C. H. S.

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National Geographic Magazine, Washington, D. C.	Gilbert H. Grosvenor
Nebraska Teacher, Lincoln	George L. Towne
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School and Home Education, Bloomington, Ill.	George Brown
School Century, Oak Park, Ill.	George W. Jones
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School News, Taylorville, Ill.	L. L. Parker
School News, Newark, N. J.	John C. Evans
Sierra Educational News, San Francisco, Calif.	Arthur Chamberlain
Southern School Journal, Lexington, Ky.	R. S. Eubank
Southern School Work, Alexandria, La.	C. R. Reagan
South Dakota Educator, Mitchell	F. L. Ransom
Texas School Journal, Dallas	H. T. Musselman
Utah Educational Review, Salt Lake City	L. E. Cowles
Wisconsin Journal of Education, Madison	W. N. Parker

The Teaching of General Science, by W. L. Eikenberry, University of Kansas at Lawrence. Pages viii + 169. 13x19.5 cms. Cloth. 1922. The University of Chicago Press, Chicago, Illinois.

It is with great pleasure that the writer undertakes a review of this most splendid book on the teaching of general science. Never has there been such a chaos on the teaching of general science and the methods of doing it as now exist in this country. Almost every teacher, or group of teachers, have a different method of approaching the subject and this book, from this well-known author and past master of the subject, fills a long-felt want. Teachers, by reading and studying this book, will unquestionably be better able to handle the subject of general science than they would without a knowledge of its contents. There is no doubt but what principals and superintendents will warmly welcome the appearance of this text, because it is going to put into the hands of every teacher, the new ones especially, a means of enabling them to accomplish their work very much more efficiently. The author has only words of praise to express for the book. The diction is perfect, the facts stated are correct, and the author has made reference to various papers and books on the subject of general science. In fact, there is a complete bibliography of the most important papers that have ever been written on the subject of general science. Contents consist of ten chapters as follows: Some historical considerations, criticism of science teaching, objectives in science teaching, the objectives of general science and method, the subject-matter of the general science course, principles of organization, examples of the organizations of general science, the general science teacher, and the complete index. Major paragraphs begin with bold-faced type which indicates the nature of the discussion in that paragraph. Each chapter has appended a list of references to the books and papers discussed in that chapter. The author has made a thorough study of all of these references and has brought together an account of all of the better papers in any way touching upon the subject of general science. The book is fitted for use in all parts of our country. It is printed on uncalendared paper, and is a book that should, without question, be in the hands of every science teacher in the country. C. H. S.

Laboratory Directions for Elementary Botany, by James B. Pollock. University of Michigan. 102 pages. 15 x 23 cms. Paper. 1922. George W. Heer, publisher, Ann Arbor, Michigan.

Without question this little manual, coming from the pen of Professor Pollock, is one of the best yet produced, as it is the result of twenty-five years' experience in teaching elementary botany to the students in the University of Michigan. The work as outlined is essentially that which is now given in the university. It is a splendid book. Instructors in elementary botany cannot do better than to use it in their class rooms.

C. H. S.

Dangers in Chemistry of Fire for Primary Schools, by F. M. Regal, Superintendent of Public Instruction, Ohio. Pages 78. 16x23.5 cms. Cloth. 1922. F. G. Heer Printing Co., Columbus, Ohio.

This is a splendid little book that has been gotten out primarily for primary schools of our country, and especially for the State of Ohio. The author discusses many of the causes of fire and how they may be prevented. Almost all of the more common elements that have led to the starting of fires are discussed. It is a book that should have a wide circulation, because it is to the point and it is made interesting for young people. C. H. S.